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THE MECHANISM OF HEREDITY AS INDICATED BY THE INHERITANCE OF LINKED CHARACTERS

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IT is generally recognized to-day that the central idea of Mendel's discovery in regard to heredity is that when two contrasting elements enter a hybrid, one from each parent, they separate in the germ-cells of the hybrid, so that the germ-cells are *pure* like those of the original parents in regard to each element.[1] Chance meetings of the germ-cells give the ratios that are characteristic of Mendelian heredity. This is illustrated by the example that Mendel gave.

When a pea having green seeds is crossed with a pea having yellow seeds a hybrid pea is produced. When the germ-cells of the hybrid are ripened, each ovule carries either the element for green or that for yellow, but never both. Yellow and green have separated. The same separation occurs in the formation of the pollen. If self-fertilization now takes place chance combinations of the yellow- or green-bearing ovules with the yellow- or green-bearing pollen give one pure yellow pea, two hybrid (yellow) peas, one pure green pea, as shown in Fig. 1.

Mendel discovered that the same principle holds when two pairs of

[1] Mendel speaks of *characters* as forming pairs. To-day we speak of factors or genes as the paired elements (allelomorphs) in the germ-cells, and these are supposed to act as differentials in producing the characters in the adult animal or plant. The English school considers the presence of a factor as one allelomorph and its absence as the contrasting factor. For instance, if yellow color is due to a present factor then if it were lost the color that results is green. But since we know nothing about the material in the germ-plasm that by interacting with other parts gives yellow in one case and green in the other, it seems to me gratuitous to postulate the nature of the change in the germ plasma. It is only necessary to assume that the original factor and a new factor form a pair without in any way committing one's self as to how these two allelomorphic factors are related to each other.

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characters are involved. If one of the original parents had round seeds and the other wrinkled seeds, these characters separate independently of the green-yellow separation. We say technically that the pair yellow and green, and the pair round and wrinkled segregate independently of each other. Chance combinations of the germ-cells in a double hybrid of this sort give nine yellow round peas, three yellow wrinkled peas, three green round peas and one green wrinkled pea (Fig. 2).

The same rule applies to three or more pairs of characters. Mendel assumed in fact that independent assortment[2] always takes place no matter how many characters are involved.

In more recent times evidence has been accumulating which shows that the chromosomes are the bearers of most of the elements (factors) that produce those characters that we study in heredity. I can not take up the work that seems to me to place this hypothesis on a very probable basis, but I shall simply assume that it is a reasonable conclusion from the evidence at hand.

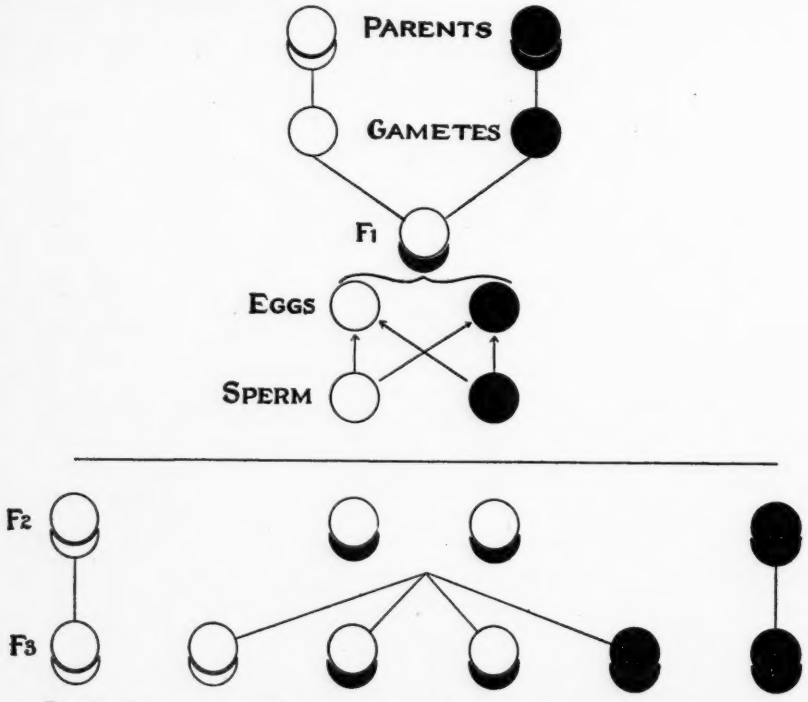

FIG. 1. Diagram to illustrate Mendel's law of segregation. Individuals (zygotes) are represented by superimposed circles, whose colors stand for the factors involved. Gametes (germ-cells) are represented by single circles.

[2] The term segregation applies strictly to the process of separation of the contrasted factors (allelomorphs). When more than one pair is involved, the distribution that follows the segregation of each pair is called assortment in the text, and assortment is a different process from segregation; although it is the resultant of segregation so far as each pair is concerned.

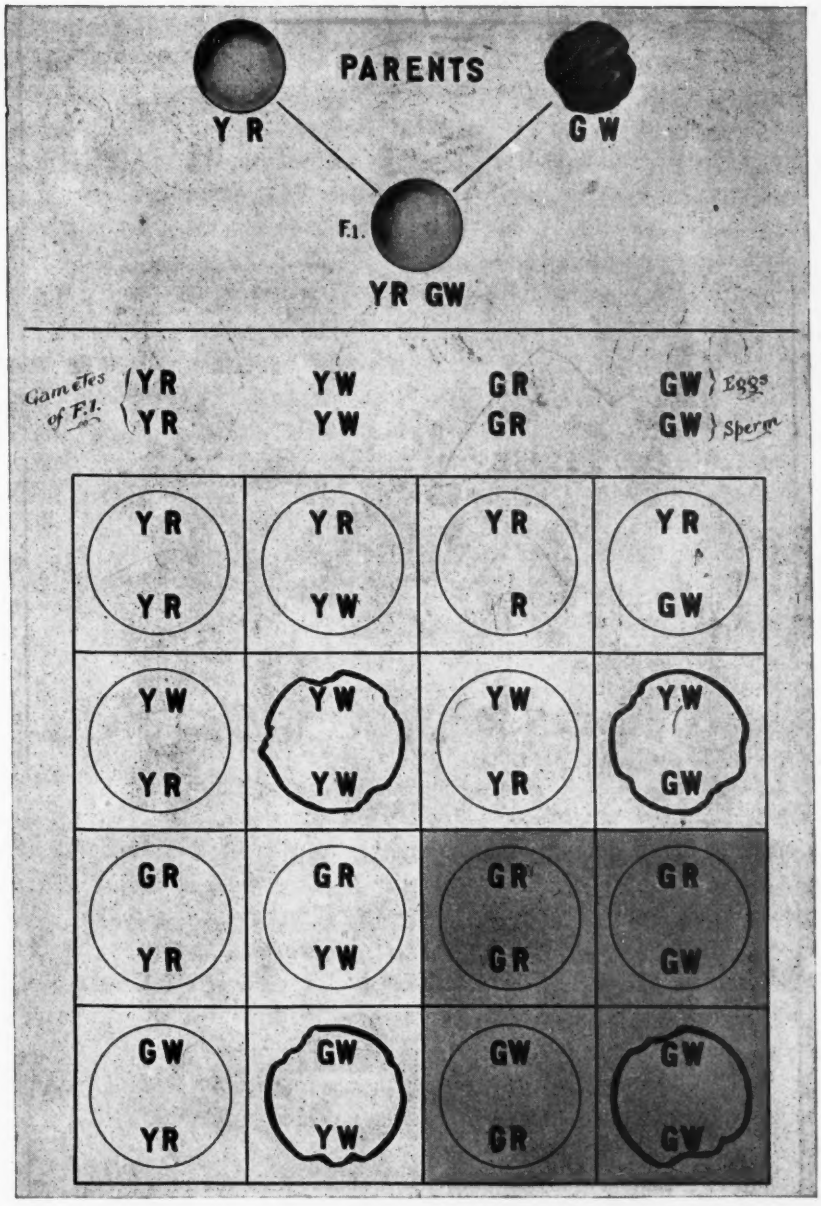

FIG. 2. Diagram to illustrate inheritance of two pairs of Mendelian characters, viz., yellow-green and round-wrinkled peas. The 16 small squares represent the composition of the 16 F_2 peas; viz., 9 YR, 3 YW, 3 GR, 1 GW.

In each animal or plant there are in general two of each kind of chromosomes.[3] One of each kind has come from the father, one from the mother, at the time of fertilization (Fig. 3, *a*). A hybrid likewise

[3] Except in those cases where the male has one less chromosome than the female. In such cases the single sex chromosome of the male has no mate.

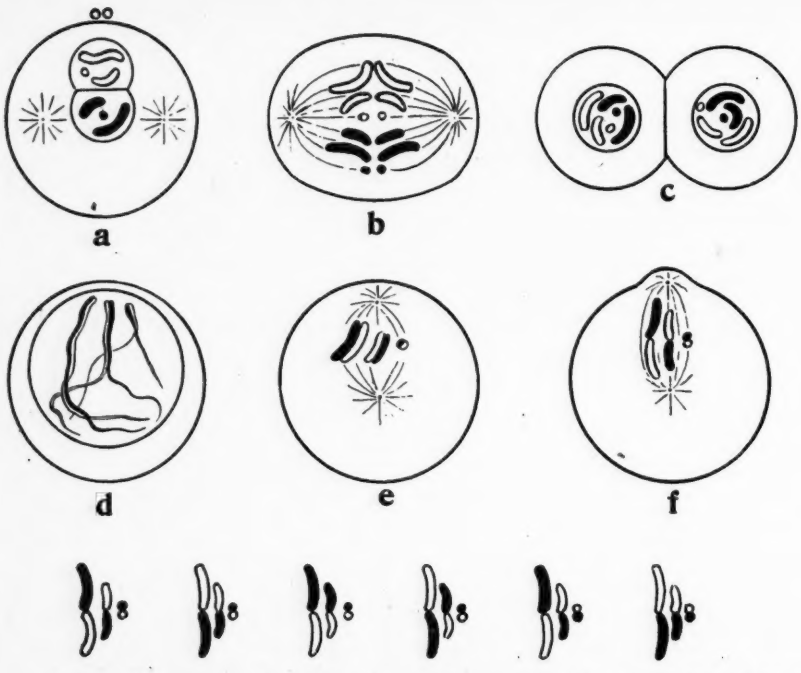

FIG. 3. Diagram to show the pairs of chromosomes (*a, c*) and their behavior at the time of maturation of the egg. Three pairs of chromosomes are represented; three from one parent, three from the other. The six possible modes of separation of these three are shown in the lowest line.

gets one of each kind of chromosome from one parent and one of each kind from the other parent. At the maturation of the germ-cells the maternal chromosomes and the paternal chromosomes come together in pairs and appear to fuse (Fig. 3, *d, e*). They then separate, and after two peculiar divisions one chromosome of each pair goes into the egg and one into the polar body. Similarly for the sperm. There is no evidence that all the maternal chromosomes go to one germ-cell, and all the paternal to the other, more frequently than chance assortment calls for, and we are free to suppose that a *random assortment* of chromosomes takes place, so that each egg and each sperm gets one of each kind regardless of its parental origin (Fig. 3, lower line).

With the acceptation of this view it appears at first sight that in a given race there can not be more independent pairs of characters that show assortment than there are pairs of chromosomes. Since the number of chromosomes is fairly limited it might appear that we could reasonably expect to make still more probable the chromosome hypothesis by finding that the number of independent pairs of Mendelian characters is not greater than the known number of chromosomes in a given race; or else we might expect to disprove the chromosome hypothesis by showing that the number of independent pairs of characters does

transcend the number of the chromosomes. As a matter of fact, several strains are known in which the number of Mendelian characters is greater than the number of chromosomes; but just here a remarkable phenomenon has come to light that shows in certain cases that many of the characters do not segregate independently, but are linked to each other as though they belonged to some common system. As a result, peculiar ratios appear, that differ from the expected Mendelian ratios in so far as that expectation rests on independent assortment. The question here raised has, therefore, taken on a new aspect, and it has become essential to discover whether there are as many, or more, or fewer groups of linked characters than there are kinds of chromosomes.

Correns appears to have been the first to call attention to a case in which peculiar ratios appeared which he attributed to coupling. Bateson and his coworkers have described several instances of the same kind. They have found that certain characters in sweet peas do not fulfill the expectation for independent assortment of different pairs of characters, although they do show Mendelian segregation when each pair is taken separately. This phenomenon has been described as coupling or repulsion.[4] I shall refer to it as linkage.

It was found, for instance, in sweet peas that when plants with blue flowers and long pollen grains were crossed to plants having red flowers and short pollen grains in the grandchildren, the blues had for the most part long pollen and the reds short pollen. Again when blue and red flowers with erect and hooded standards were used all the red grandchildren had erect standards.

We have met with these same phenomena at nearly every step in our studies of heredity in the fruit fly, *Drosophila*. Over one hundred mutants have appeared from many of which pure races have been formed. At present we have studied fifty-nine of these sufficiently to show that they fall into three great groups.

The characters in the first group show sex-linked inheritance. They follow the sex chromosomes. The second group is less extensive. Since the characters in this group are linked to each other we say that they lie in a second chromosome. The characters of the third group have not as yet been so fully studied, except to show that they are linked. We

[4] Bateson and Punnett formerly defined coupling as the association of two factors and repulsion ("spurious allelomorphism") as the condition where two factors are usually not associated in the same gamete. They point out that the same idea is expressed by saying that if two dominants come from one parent and two recessives from the other coupling is observed; but if one dominant and one recessive come from each parent, repulsion will be found. For the fly, *Drosophila*, we have pointed out (*Jour. Expt. Zool.*, 1911) how both these results can be accounted for on the hypothesis that the factors concerned are carried by the chromosomes. Bateson has more recently changed his conception of coupling and repulsion.

place them in the third chromosome without any pretensions as to which of the pairs of chromosomes are numbered II. and III.

The arrangement of these characters in groups is based on a general fact in regard to their behavior in heredity, viz., *A member of any group shows linkage with all other members of that group, but shows independent assortment with any member of any other group.* In *Drosophila ampelophila* there are five pairs of chromosomes. According to Stevens, the sex chromosomes are attached to one of the other pairs. Three of the five pairs are occupied according to our view by the three groups of linked factors that we have studied. There are as yet two more pairs of chromosomes than there are groups of linked factors.

On the chromosome hypothesis we can readily see that if the factors that stand for characters lie in the chromosomes, those that lie in the different chromosomes should give independent assortment, and the ratios obtained in breeding experiments should be the expected Mendelian ratios. On the other hand, it may appear that the factors that lie in the same chromosomes should always march together through successive generations. If this were true the linked characters would be absolutely linked to each other. Experience shows, however, that the linked characters are not absolutely linked, but that to a greater or a less degree, according to the factors involved, interchanges must in some way take place. Here fortunately there is a cytological relation that may be utilized to explain how interchanges between like chromosomes may take place.

It has been observed when the homologous pairs of chromosomes unite before maturation of the egg and sperm that they twist around each other. In consequence, parts of each chromosome may come to lie on one side of the twist and other parts on the other side. If at times the chromosomes break at the crossing point, and each then unites with that part of the other chromosome that lies on the same side, the new chromosomes that emerge later from the pair will be made up of parts of each chromosome to the extent to which breaking has taken place at some of the crossed levels.[5]

[5] The twisting of the chromosomes has been described by a number of writers. Janssens has observed that at the time when the pairs are about to separate, cross-bridges between the pairs (more strictly between the halves of the pairs) can be seen. Whether these cross-bridges are the result of the kind of crossing referred to in the text can not be discussed here. Janssens points out that the mechanism of interchange between homologous chromosomes, by means of the cross-bridges furnishes an interesting explanation of those cases where the number of distinct allelomorphic pairs of characters is greater than the pairs of distinct chromosomes. The evidence seems to me to indicate furthermore that independent assortment occurs when factors lie in different chromosomes, while the interchange between homologous chromosomes accounts only for the relatively small proportion of crossing-over. Only when the factors lie very far apart is there a numerical approach to the independent assortment of factors lying in different chromosomes.

In consequence the two new chromosomes are no longer made up of the same parts as the original chromosomes, but of pieces of both. If we think of all the factors that lie in one chromosome as linked because ordinarily they go together, in the sense that they are likely to remain in that chromosome, this linkage will be disturbed, or broken, at one time only in the history of the chromosomes, viz., at the time of conjugation of the pairs, when an interchange between the members of an homologous pair becomes possible.

Let me illustrate by means of two concrete cases, and by preference cases that belong to the sex chromosomes, because the conditions here are simpler and more convincing, and because we have more definite information concerning the mode of distribution of these chromosomes than of any other.

When a male fruit fly with yellow body color and white eyes is mated

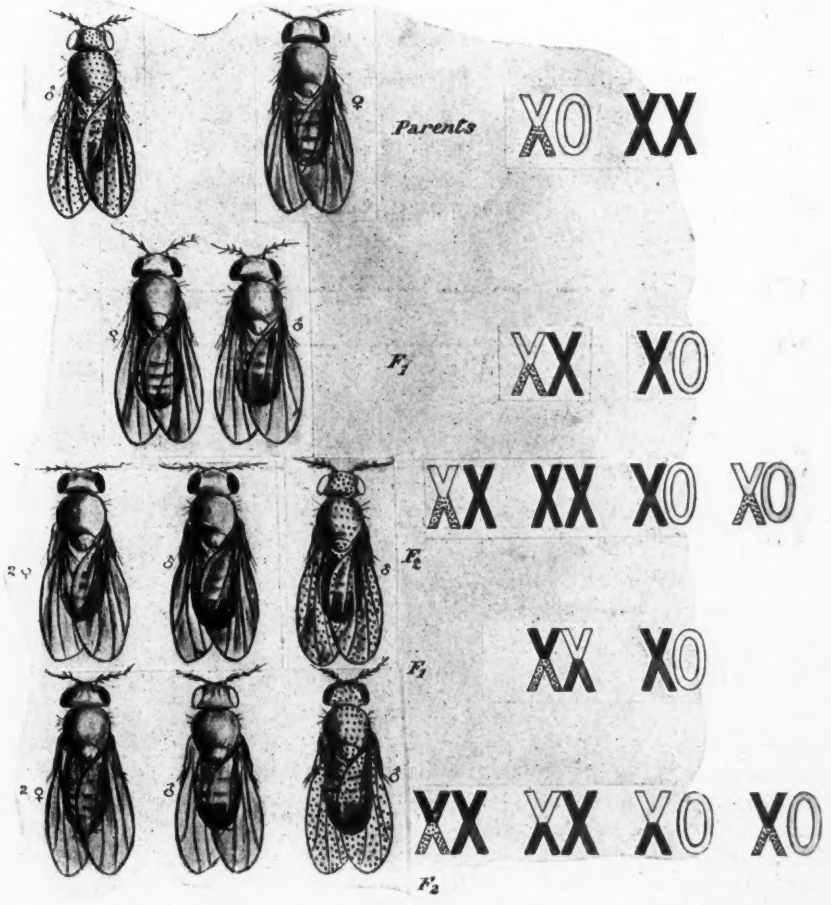

FIG. 4. Diagram illustrating the results of crossing a yellow (stippled), white-eyed male to a gray, red-eyed female of *Drosophila*. To the right the sex chromosomes are represented, colored in the same way as the flies.

to a gray (wild) female with red eyes, the daughters are gray with red eyes, and the sons also (Fig. 4). The explanation of this result is shown in the diagram in which the sex chromosomes are represented by X's which are marked like the characters they stand for. The daughter gets a "red-gray" chromosome from the mother and a "white-yellow" chromosome from the father. Since red and gray dominate the color is determined by these factors. The son gets his single sex chromosome from his mother which carries the factors for gray body color and red eyes.

When the hybrid (F_1) flies are inbred they produce one kind of female and four kinds of males as shown in the next figure. In order to understand how these classes arise let us follow the history of the sex chromosomes.

The F_1 female had two kinds of sex chromosomes, that we may call briefly WX and RX. Either may pass out into the polar body leaving the other chromosome in the egg. Consequently there are two kinds of eggs. The F_1 male has only one sex chromosome GRX which goes into the female-producing spermatozoon. The other, the male-producing spermatozoon, does not carry an X chromosome. When the female-producing sperm fertilizes either kind of egg it brings in the two dominant factors GR; hence all the females are gray in body color and have red eyes. Since the male-producing sperm does not bring into the egg

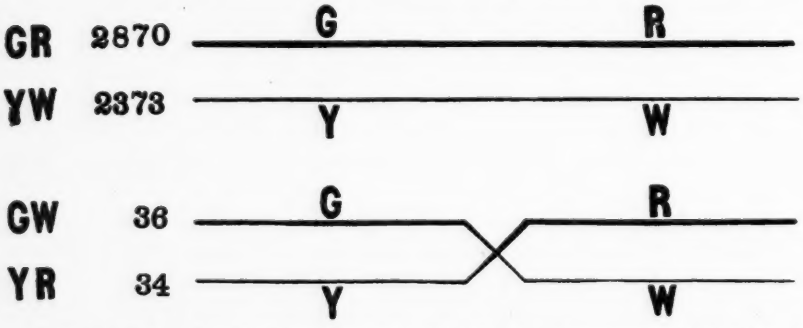

FIG. 5. The two upper lines represent the two sex chromosomes of the female, showing their original composition, viz., GR and YW. The lower line shows "crossing-over" between the two pairs. The numerals to the left give the F_2 males, whose composition is the same as that of the chromosome that stands next to them. The males receive one or the other of these chromosomes from their mother.

any X chromosome, the sex-linked factors in that egg are those of the egg itself. Since without interchange between the sex chromosomes there are two kinds of eggs there will be two kinds of males, namely, gray-white and yellow-red.

But the experiment shows that there are *four kinds* of males. Their origin can be explained if we assume that in some of the eggs the sex chromosomes prior to the extrusion of the polar bodies have crossed,

and the parts have reunited at some point between the factors in question. This is shown in the next diagram (Fig. 5) where the crossing over is represented. The number of times that this occurs will be measured by the number of the two other classes of males, the gray-red and the yellow-white. The actual results are:

GR♀	GR♂	GW♂	YR♂	YW♂
6080	2870	36	34	2373

Expressed in percentages the crossing over takes place in 1.3 per cent. of the total number of males produced.

The hypothesis of independent assortment for two pairs of characters calls for equal numbers in each of the four classes of males in the cross just given. The numbers show how far the actual results depart from this expectation.

There is one further point here that demands consideration. If the factors lie in a linear order in the chromosome as the hypothesis requires it is evident that the nearer together two factors lie the smaller will be the chance that a twist occurs between them. Consequently the frequency of crossing over can be taken as a measure of the distance of the factors from each other in the chromosome. On this basis the position of these factors in the chromosomes has been calculated. I shall return to this point later.

When three pairs of sex-linked characters are involved the result is essentially the same, but the possibility of another class of individuals, viz., those produced by double crossing over offers certain relations of peculiar interest. If a female fly with the characters yellow body color, white eyes and miniature wings is mated to a wild male with gray body color, red eyes, and long wings the daughters are like the father and the

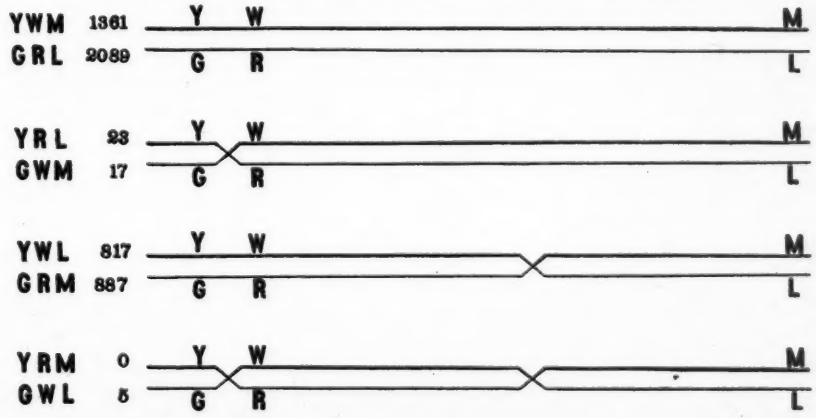

FIG. 6. Diagram illustrating the two sex chromosomes in the F_1 female derived from a YWM female and a GRL male. The first (upper) pair of lines show the chromosomes without crossing over. To the left the number of the F_2 flies of the composition of the two chromosomes respectively are represented. The second pair of lines illustrate the results of "single crossing-over" between YW and GR. The third pair of lines represent the "single crossing-over" between WM and RL. The fourth pair of lines represent the results of "double crossing-over."

sons are like the mother. The explanation is here the same as in the last case. These inbred give the following significant classes:

GRL	YWM	GWM	YRL	GRM	YWL	GWL	YRM
1483	1265	16	16	720	684	4	0

The diagram, Fig. 6, shows the imagined relation of the chromosomes to each other. There are two classes, YWM, GRL, representing "non-crossing-over." There are four classes, YRL, GWM, YWL, GRM, where "single crossing-over" is expected. There are also two classes, YRM, GWL, representing "double crossing-over."

Other experiments show that the factor for miniature gives a high percentage (about 34) of cross-overs with yellow or with white. We place it at a correspondingly distant point which means that the likelihood of a twist occurring between the loci for miniature and that for yellow (or for white) is large. Other experiments show that the factor for yellow body color and that for white eyes rarely cross over. We place them therefore near together. The chance that a twist should occur between Y and W and at the same time another twist between W and M is very small. It is to be anticipated that the double crossing-over would be rare, as it is, in fact.[6]

I have given the argument on which we base our scheme of the linear order of the factors in the chromosomes. I need hardly say that there is no pretension that the distances (calculated in per cent.) correspond to real distances, for we know nothing of the actual space occupied. But the numbers give the *relative* positions of the loci in the chromosomes. The procedure justifies itself in one all-important respect. By its means we can calculate results before they are tried, and experience shows that the prediction comes true. For example, if we know the location of a factor Y and of another factor W, then when a new factor, M, appears we need only determine its position in regard to Y and we can predict what will happen when a cross is made between M and W. In a word, we can by determining the position of a new factor in regard to any other known factor calculate the results for all other known factors in the same chromosome. When we recall the wide departure, due to linkage, from the accepted Mendelian ratios based on random assortment it is no small gain to be able to calculate the results of all possible combinations by determining two known points. I make this statement even though we may at any time find that linkage is influenced by the environment, or by characteristics peculiar to individuals or to pure strains. Nothing would be more harmful at this stage than that the situation be prejudiced by absolute statements.

If any one objects to locating these points in chromosomes and pre-

[6] The first and best description of double crossing over is to be found in Sturtevant's paper (*Jour. Expt. Zool.*, 1913).

fers to treat biological problems in terms of mathematics he can make the same predictions from the data that can be treated without regard to the mechanism of the chromosomes. But since we find in the chromosomes all the machinery actually at hand for carrying out this procedure, it seems to me reasonable to base our conceptions on this mechanism until another is forthcoming. And if it should prove true that we have found the actual mechanism in the organism that accounts for segregation, assortment and linkage of hereditary factors we have made a distinct advance in our study of the constitution of the germ plasm.

It has been pointed out to me, more than once, that the views here presented concerning the "architecture" of the chromosome are similar to the views (assumed to be discredited) that Weismann advanced several years ago. But it should not be overlooked that Weismann's purpose in locating his determinants in the chromosomes was only that he might separate them again during development. He tried, in fact, to explain development in this way without, however, explaining what determines during development the *orderly disintegration* of the chromosomes. Nothing of the sort is postulated, or implied, on my view. Weismann's hypothesis was purely speculative. My own conception of the constitution of the chromosomes rests on numerical data obtained from hereditary characters. All of the chromosomes are supposed to go intact to every cell of the body as observation, so far as it goes, shows to be the case. How differentiation takes place is a question quite remote from the idea of the architecture of the chromosomes in their relation to hereditary characters.

There is but one fundamental similarity between my own view and that of Weismann. The chromosomes, looked upon as the vehicles of heredity, are assumed by both of us to have definite structures and not to be simply bags filled with a homogeneous fluid. The discrete parts (factors) of these structures are supposed to influence the course of differentiation, but there the resemblance ends. A factor, as I conceive it, is some minute particle of the chromosome whose presence in the cell influences the physiological processes that go on in the cell. Such a factor is supposed to be one element only in producing characters of the body. All the rest of the cell or much of it (including the inherited cytoplasm) may take part in producing the characters. So far as such things as unit characters exist I look upon them merely as the most conspicuous result of the activity of some part of the chromosome. A single factor may affect all parts of the body visibly, or a factor may preponderantly influence only a limited section of the body. As a matter of fact, if we look carefully, we can generally find far-reaching effects of single factors. On the other hand, Weismann's idea of development emphasizes the intimate relation between his determinant and a specific character of the body. His writings often leave the

impression that he supposes the determinants of the chromosomes to pass out into the cell, multiply there, and become the differentiated part. Perhaps this is only due to his attempt to visualize his conception, and he might grant that the differentiation of the determinants may depend on the interaction of many parts of the cell. But if we take his view literally to mean that the determinants are the materials out of which specific structures are directly built up, then his conception of the nature of a determinant is widely different from my own concerning the relation of "factors" and body characters.

THE PRESENT STATUS OF CANCER RESEARCH

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IT is well known that all organisms, plants as well as animals, are composed of small units—the so-called cells—in which a nucleus is surrounded by protoplasm and certain special structures. Each part of the animal body is formed by aggregations of different kinds of cells. The skin and the cavities within the body as well as the glands are composed of epithelial cells, the bones and muscles are produced by special bone and muscle cells. Uniting the various special structures and cell-layers in the body, we find the so-called connective tissue consisting of special cells (connective tissue cells) and their product, the connective tissue fibers.

In the normal adult organism some kinds of cells are entirely or almost at a standstill as far as their growth (increase in number and size of cells) is concerned, while other kinds of cells are continually propagating. However, as for each newly formed cell an old one is cast off, no actual increase in the number of cells takes place during adult life under normal conditions. If, however, a small part of the body, *e. g.*, the skin, is removed, the neighboring cells begin to proliferate, and soon fill out the defect. We call this kind of growth regenerative. Very energetic cell proliferation of course is necessary for the transformation of an ovum into the fully developed young organism. This growth, which ceases as soon as the definite organism has been formed and the various organs have been differentiated, we call embryonic growth. A very interesting rapid cell proliferation takes place also in the uterus after the insertion of the ovum, leading to the formation of the maternal placenta.

In the normal adult organism, a definite equilibrium exists between the different kinds of cell aggregations which we call tissues. Each kind of cell respects the territory of the neighboring cells. Not rarely it happens however that suddenly in a young or adult organism cells in a certain part of the body begin to proliferate in an unusual manner; they multiply more or less rapidly. This growth can not be called regenerative, because there was no primary defect to be filled out, and if there had been such a defect the proliferation does not limit itself to wound healing. This multiplication of cells leads to a definite swelling in a certain part of the body. We call it a tumor. The aggregation of

newly formed cells may form a well-defined mass which simply pushes aside the neighboring parts of the body. After some time the growth may entirely cease or it proceeds usually slowly. In this case we speak of a "benign" tumor. In many other cases, however, the newly formed cells not only multiply, but they also invade the neighboring tissues either as isolated cells or in clusters of cells. Each cell which migrates in the neighboring territory becomes again the center for the formation of a new tumor inasmuch as it has the power for indefinite propagation. Other cells even invade the lymph or blood channels of the body, and are carried with the lymph or blood stream to different parts of the body. At certain places they can not pass the narrow passages, they remain attached to the vessel wall, begin again to multiply, to break through the vessel wall into the neighboring tissue and produce at various places, often distant from the original site of the tumor, secondary tumors which are called metastases. This infiltrating, metastatizing tumor we call a malignant growth or a cancer. According to the kind of cells which form the cancer and according to the proliferative and infiltrative energy of the cells composing the growth we distinguish many varieties of cancer. There are morphological as well as physiological differences between different varieties of cancer. Roughly we may however classify the various cancers in those derived from epithelial tissue (for instance of the skin, stomach, uterus, the various glands) which we call carcinomata and those derived from proliferating connective tissue cells. Connective tissue in any part of the body may give rise to cancer. These connective tissue cancers are called sarcoma. The growth of a cancer exerts injurious influences on the organism as a whole. Through pressure on neighboring organs it often interferes with important functions of the digestive, respiratory, excretory organs, and leads to serious disturbances of metabolism. It often breaks through the epithelial membranes of the skin or of the inner cavities of the body; under those conditions parts of the tumor die, break down, and are cast off; an ulcerative surface is thus produced which serves as a place where certain bacteria find a favorable culture medium; putrefaction takes place and the absorption of the putrid material further weakens the organism. But even without the formation of an ulcer, parts of the tumor which are under unfavorable conditions of nourishment constantly die (become "necrotic"), while neighboring parts continue to grow. The absorption of the necrotic material may also exert an unfavorable influence on the metabolism. It is furthermore very probable that the living tumor cells give off certain substances which differ quantitatively or qualitatively from the substances produced in the normal organism, but whether these latter substances exert a toxic influence on the organism it is impossible to state at the present time. Cancer almost invariably progresses continuously and it is

doubtful whether it ever disappears spontaneously. It is therefore a disease which leads without special interference to the death of the patient, sometimes very soon, sometimes many years after the first symptoms appear, according to the rapidity of the growth of the cancer. The characteristic feature of cancer as a disease may therefore be stated as follows: Cancer consists in an abnormal multiplication of cells at a certain, at first, usually well-defined place of the body. All the deleterious results are primarily produced through this continuous growth which spreads into different parts of the body. This growth as such through the pressure it exerts on neighboring organs or through its infiltration into and destruction of vital parts of the body leads to the death of the affected individual, secondarily toxic influences may be added to the primary results of the growth; but these toxic influences are as far as we know not of a specific character. It is different in the so-called infectious diseases. There the disease consists primarily in an intoxication by products given off by the invading organisms and a proliferation of the body cells plays only a subordinate rôle in the disease process.

While we can thus, in a rough way, define and differentiate cancer from certain other diseases, we must be well aware of the fact that a complete and satisfactory definition of a process can be given only after the completion of its scientific analysis. Usually, however, definitions are given in the beginning of the study of a certain process; and they have therefore only a provisional value. Certain apparent, often superficial features are at first used for characterization. During the progress of scientific investigation new relationships to neighboring fields are discovered, differences which at first appeared to be of a qualitative are gradually to be found to be merely of a quantitative character. Thus we must prepare for the eventuality that the sharp differentiation between cancer and infectious or toxic diseases may not be upheld through future investigations. In fact already at the present time we know of conditions which seem to be intermediate between the two sets of phenomena and it is probable that we will gradually have to add certain subdivisions defining conditions which have factors in common both with cancer and the so-called infectious diseases. At present it is of comparatively little importance to discuss whether certain intermediate phenomena are to be classed as cancer or infectious disease, while it is of the greatest importance to describe and analyze the character of these intermediate phenomena. In a similar manner, it is of relatively slight importance to justify or deny the admissibility of calling certain processes in animals and plants cancer—the definition of cancer necessarily being a provisional one—while it is of the greatest importance to discover similarities between certain tumor-like conditions in man, animals and plants.

We have various methods for approaching the cancer problem. We can observe the frequency with which human cancer appears, its symptoms, and conditions which precede it. We can study the finer structure and mode of development of cancer with the microscope on pieces of tumor which have been excised. We can study cancer from a comparative point of view, its occurrence in animals and plants. The comparative study leads to the experimental investigation of cancer in animals.

1. Frequency, Distribution, Varieties of Human Cancer

Cancer among man is found in all countries where a closer search for it has been instituted. The frequency with which it occurs differs, however, very much among people living under the ordinary conditions of present civilization in Europe and America and among races or nations living under more primitive conditions, especially in Africa and Asia.

If we consider first the former category we find that approximately 3.1–5 per cent. of all human beings die from cancer. We are struck by the relative uniformity in the percentage of deaths from cancer, which indicates that within certain limits the conditions causing cancer are relatively constant and uniformly distributed over the civilized world. In this respect cancer resembles certain diseases which are caused by organisms evenly distributed over wide areas and to diseases primarily due to internal factors and not or only secondarily to parasitic agencies, while it differs from such diseases as smallpox, bubonic plague and poliomyelitis which are very irregular in their appearance.

If we compare the death rate from cancer in various countries we find the following figures: In a population of 10,000 die from cancer each year: in Switzerland 13.2, Norway 10, Holland 10.1, England 9.1, Austria 7.8, France 7.6, Prussia 7.1, Italy 6.1, Spain 4.8, Algiers (European inhabitants) 3.2. The death rate is also relatively low in Russia, Hungary, Servia, Jamaica and Ceylon. In Kyoto (Japan) it is approximately like Austria 7.9 per 10,000 inhabitants. On the whole the death rate from cancer is low in the countries around the Mediterranean.

In the United States in an area comprising one half of the population, the death rate per 10,000 inhabitants was (according to a report by the Health Commissioner of Pennsylvania (Dr. S. C. Dixon), 7.31 in 1907; the death rate in the United States is therefore very similar to that of Germany and Austria. Approximately 75,000 people die from cancer in one year in the United States and about half a million in the civilized world (F. L. Hoffman). If we consider only persons over 45 years old, considerably more people in the registered area of the United States die from cancer than from tuberculosis. Between the age of 45 and 60 years almost 7 per cent. of the male and 16 per cent. of the female population die in this country from cancer.

If we compare the death rate from cancer in the last 40 or 50 years we notice a universal increase in all civilized countries. The increase has taken place rather steadily and not by leaps. According to W. J. Whitney there was in Massachusetts from 1850–1910 during each 5 years an average but not quite uniform increase of 1.20 in the death rate for 10,000 persons over 30 years of age every five years. According to Dr. S. C. Dixon in an area comprising one half of the United States in population the death rate increased from 4.79 (1890)–7.31 (1907). In New York City there has been an increase from 5.4, which was the death rate during the 4 years ending 1882 to 8.1 during 1908–1912. A similar increase we notice in Germany, Norway, Amsterdam and everywhere else, where statistics are available.

While there can therefore be no doubt as to the actual increase in the death rate from cancer, the interpretation of this phenomenon is not quite clear. While some authors believe in a real increase, others believe it to be only apparent, due to improvements in diagnosis and to better registration. It is pointed out by some authors (especially by Bashford) that the increase in the death rate is found mainly in internal cancers which are difficult to diagnose. The increase concerns to a great extent cancer in the alimentary tract. This increase is found especially in persons over 60 years of age. Now in children cancer not rarely attacks internal organs, and still no noteworthy increase is reported in those cases. Furthermore errors in diagnosis would equally prevent physicians from diagnosing as cancer cases which are not cancer as well as from attributing to other causes deaths really due to cancer.

Furthermore the same increase has been noted in the well-conducted autopsies in the Charité Hospital in Berlin, where the diagnostic methods have not to any considerable extent changed within the last thirty-five years. According to Professor Orth, in autopsies on persons over 20 years of age cancer was found from 1875–1885 in 4 per cent., in 1904 in 10.7, 1909 in 19, 1911 in 20.8 of all the cases. It is, therefore, probable that a certain factor which is potent in the production of cancer has been gradually changed within the last fifty years causing a general increase in the cancer rate, while at the same time there has been a marked decrease in the death rate from tuberculosis in the corresponding period.

We will now consider the relative frequency of the different varieties of human cancer. Here we find again a similar distribution of the various kinds of cancer in all civilized countries in Europe, America and as far as we can judge at the present time also in Japan. The most frequent seat of cancer is the gastro-intestinal tract, especially the stomach, and in the second place the female generative organs, especially the cervix of the uterus and the female breast. Cancer of the stomach is approximately equally frequent in man and woman; in

some countries it is slightly more prevalent among men. On the average 35–45 per cent. of all cancer affects the stomach and about 22 per cent. of all cancers develop in the female generative organs and breast. About 20–35 per cent. of all women who die from cancer have cancer of the uterus. Cancer occurs also relatively frequently at the lip, tongue, rectum and skin, especially of the face. Sarcoma is much less frequent than carcinoma. The relative frequency of the different varieties of cancer in the most populous areas of the United States is (according to S. C. Dixon) as follows: mouth 3.2 per cent., stomach and liver 38 per cent., intestines 11.7 per cent., female generative organs 14.3 per cent., breast 8.5 per cent., skin 3.7 per cent.

There occur, however, some notable deviations from the average rate of the different varieties in some countries. In Norway cancer of the uterus is relatively rare; only 6.3 per cent. of cancer develop in the uterus and 3.8 per cent. in the breast. In some parts of Norway cancer of the uterus is almost unknown. Cancer of the gastro-intestinal tract preponderates therefore considerably in Norway. In Sweden on the other hand cancer of the uterus is only slightly less frequent than elsewhere. In Switzerland also cancer of the stomach preponderates somewhat more than in the majority of other countries. A very peculiar deviation we find furthermore in Portugal, where cancer of the lip is very much more frequent than elsewhere (29 per cent. in men). While, on the whole, carcinoma of the male generative organs is rare (0.4 per cent. of all kinds in man), it is very frequent in the Cape Verde Islands. The proportion of cancer of the respiratory and excretory organs (kidney, ureter, bladder) is everywhere relatively low.

If we compare the incidence of cancer in the two sexes we find in most countries women somewhat more frequently affected than men. In Prussia the proportion is 3 men to 4 women. The relative incidence in women is even somewhat greater in the United States. The difference depends upon the difference with which various kinds of cancer affect the two sexes, and mainly upon the frequency of cancer in the female generative organs and breast; cancer of the gall-bladder, intestines, especially rectum, is also more frequent in women than in men, while cancer of the lip, tongue, skin, is more frequent in men. Cancer of the stomach is either equally frequent in both sexes or somewhat more frequent in men. In countries where cancer of the stomach prevails, and where a larger proportion of men than women are affected by this kind of cancer, the cancer death rate is higher in men, as in Switzerland, Norway and Kyoto (Japan).

There is no marked difference between married and single persons; the majority of statistical studies, however, indicate that married women are more frequently affected by cancer of the uterus and breast than unmarried women.

Sometimes we find the statement made that cancer is more frequent among the well to do than among the poor. It is doubtful whether this statement is correct. Some recent statistics point rather to the reverse. Again there seems to be in this respect some difference in the various kinds of cancer. Cancer of the cervix of the uterus appears to be more frequent among the poor, while mammary cancer is perhaps more frequent among the well to do.

There exists no marked difference in the incidence of cancer in country and city. On the whole, we are apt to find a somewhat greater incidence of cancer in the cities, especially in parts of the world where the number of physicians per unit of population is considerably smaller in the country and where therefore in all probability the number of unrecognized cases of cancer is greater in the country. The difference is therefore probably rather apparent than real.

There have been noted in various countries certain areas where cancer appeared to be more frequent than in others. Some observers believed especially damp-wooded country to be favorable to the development of cancer. Some physicians recognized certain houses or streets in villages or small towns, where the incidence of cancer was especially great. Behla for instance reported such an occurrence in the small Pommeranian town Luckau. These observers declared cancer to be "endemic" in certain localities and were often inclined to attribute this localized increased frequency to unknown infectious agencies. Although it is very difficult to interpret these observations, it does at present not appear probable that they ought to be referred to infection. Such cancer houses have been found only rarely: the number of cancers that occurred in these houses were relatively few, and furthermore cancer occurred also in the neighboring districts. Neither can we exclude the possibility that hereditary factors played a part in some of these cases. There is, however, no doubt that in certain parts of various countries cancer is more frequent than in others.

So far we have considered the incidence of cancer mainly among the white population of Europe and America. The incidence of cancer among certain races living under more primitive conditions is quite different. Among the negroes of Africa cancer is much rarer than among the whites of Europe and America. Although according to von Hansemann the same varieties of cancer occur there as in civilized countries, the proportion of the various kinds of cancers differs markedly. We find among the African negroes relatively frequently benign tumors of the connective tissue group as for instance lipomata (fat tumors). Sarcomata are correspondingly much more frequent than among the Europeans and it is furthermore very probable that the relative frequency of the various kinds of carcinomata is different. Also among the Arabs of Algiers sarcoma is more common than car-

cinoma. Among the male Arabs nine tenths of all cases of carcinoma occur in the face, which is especially exposed to the rays of the sun, and in the women carcinoma is more frequent in the vagina than in the uterus. Carcinoma of the gastro-intestinal tract is relatively rare. Also among the inhabitants of East India and Ceylon and among the Chinese we find a lower cancer rate than in Europe. In Japan however cancer seems to be relatively frequent as far as the available statistics indicate.

Also among the Indians in the reservation of the United States cancer is considerably rarer than among the white population (J. Levin). Differences in climate can therefore not be held responsible for these great differences in the cancer incidence. But is it due to inheritable race characteristics or differences in mode of living, preceding infection with other diseases? This question we can not answer definitely at the present time. Some facts however are of interest in this connection. W. Renne found that among the natives of Sierra Leone cancer is very rare; but since a more intimate intercourse between the natives and immigrated whites has taken place, cancer has increased in Sierra Leone. But even in this case we are unable to decide whether this increase is due to changes in the conditions in life or to the intermarriage between whites and natives. In the United States we also find that within the last fifty years there has been a considerable increase in the cancer incidence among the colored population. Cancer of the uterus, which was formerly rare among colored women, is now more frequent among the colored population than among the white. Here again we can not be sure how much of this increase is due to changes in the mode of living, to increase in the inflammatory conditions of the uterus, and how much to intermarriage.

In the case of the relative rarity of uterine cancer among Norwegian women, we again do not know whether it is due to the relative infrequency of preceding infections of the uterus or whether it is a question of race. Interesting problems thus present themselves as to the relative importance of race and of external conditions in the origin of cancer. More definite knowledge could be gained if in statistics a distinction were made between negroes and mulattoes; it would also be of interest to establish the frequency of uterine cancer in the first and second generation of Norwegian women in this country, especially distinguishing between those interspersed among the rest of the population and those living in close rural communities in which the original customs are preserved.

We mentioned already that on the whole carcinoma occurs especially in old age. In the United States the average of death from carcinoma is 60 years for males and 58 years for females. Between 45 and 64 years 7 per cent. of all deaths in the male and 16 per cent. of all

deaths in the female sex are due to cancer (Hoffman). From the thirty-fifth year on the death rate from cancer increases rapidly. There seems to be an optimal age for the appearance of certain cancers which differs somewhat in various kinds of cancer. Whether the death rate from cancer as a whole increases with advancing age or whether there occurs a maximal death rate at a certain age after which there is again a decrease observed does not appear to be certain.

While the typical cancers which we have considered so far occur in the large majority of cases in older people, some cancers of the same type may appear in young people; thus carcinoma of the stomach, tongue, esophagus, appeared in very rare cases in children. But there are special kinds of cancer which appear typically in younger persons. This applies for instance to the "carcinoid" tumor of the appendix and to similar often multiple carcinomata of the small intestines, which are found in relatively young adults (Bunting). These tumors are much more benign than the typical carcinomata—they grow very slowly and make ordinarily no metastases. But certain tumors are quite typical for young children. While in adults carcinomata are considerably more frequent than sarcomata, in children sarcomata are much more numerous than carcinomata. The most frequent seats of cancer in children are neither the gastro-intestinal tract nor the female generative organs, but kidney and adrenal, next the eye, brain, skin, cranium and liver. And while the few carcinomata of the stomach and intestines in childhood are observed in 12–14 year old children, the tumors of the kidney appear often in infants.

Besides the sarcomata we find in young children frequently so-called mixed tumors, consisting of several kinds of tissue; in the kidney tumors for instance we may find side by side proliferating epithelial gland tissue, round cells resembling sarcoma, muscle and even bone-like tissue. In other organs also we find not rarely such mixed tumors to prevail among the cancers in children. Cancer of the female generative organs occurs in children not mainly in the uterus, as is the case in adults, but in the ovaries and in the vagina. In the eye and brain we find besides sarcomata which originate from connective tissue cells certain special kinds of structures, the so-called glia cells—which are related to nerve cells—to give origin to malignant tumors. Even in the abdominal organs there may appear in young persons tumor-like proliferations of cells derived from the sympathetic nervous system (Neuroblastoma of J. H. Wright).

There is still another class of tumors which occur especially in children and in young adults, but may occasionally be observed even in older people and which are of great interest, the so-called teratomata or embryomata. They have certain seats of predilection, as for instance in the pelvis in front of the sacral bone, or in the anterior mediastinum,

even in the buccal cavity; however most frequently they are found in the ovaries and testicles. In these tumors are observed a great variety not only of ordinary tissues but of incompletely developed organs, as brain, eye, lungs, gut. These structures represent evidently malformed embryos. At first they grow usually slowly—in contradistinction to the typical mixed kidney tumors of children—but not infrequently somewhat later in life one or several of their constituent parts begin to assume a malignant growth, and even produce metastases.

Now the large majority of these tumors which appear in early childhood are in all probability congenital, they were preformed before the child was born; they are, however, usually noticed only at a time when they begin to grow somewhat more rapidly, and this may take place many years after birth; thus the sacral embryomata are often noticed first somewhere between the fifteenth and twenty-fifth years, when they begin to enlarge a little, and certain kidney tumors developing in all probability from misplaced embryonal adrenal tissue may even not become apparent until later in life. We may furthermore conclude that these congenital tumors of childhood and young adult life are in part due to localized aberrations during embryonic development, their composition of a mixture of tissues suggesting similar combinations of tissues which existed at such places some time during embryonic development. At that period certain tissues did not differentiate normally, did not become a functionating part of the organism restricted in its growth—but somehow preserved a part of the proliferative power which not fully differentiated embryonic cells usually possess and they exerted a destructive influence on the otherwise normally developed organism. The famous pathologist Cohnheim especially emphasized this origin of tumors; but he and still more so some of his pupils and followers extended the significance of their observations too far, explaining on this basis the origin of tumors in general, while their conclusion applies in all probability only to that class of tumors which appear in childhood and early adult life and perhaps to certain other related tumors. Recent investigations of Robert Meyer and others have indeed shown that certain minor embryonic malformations, especially in the region of the kidneys, the thyroid, thymus and eye are quite frequent; but that in the large majority of cases they certainly do not lead to tumor formation.

Other more or less benign tumors, which are often multiple, occurring simultaneously at different places are also frequently congenital, as for instance, growths consisting of lymph or blood vessels, cartilage, muscle tissue developing around small blood vessels, and fibrous tissue growths around nerves in certain areas of the body, furthermore pigmented moles.

However, not all the tumors found in the first half of life develop on

the basis of embryonic malformations. It is very probable that many embryomata especially those of the ovaries and testicles owe their origin to the parthenogenetic development (development without previous fertilization) of a germ cell, a suggestion made more probable through the discovery of Jacques Loeb that in various classes of invertebrates ova can be induced by artificial means to develop without previous fertilization. And yet the majority of pathologists believe with Bonnet and Marchand that such embryomata just as other mixed tumors of childhood are due to embryonic aberrations, to a separation of early cells which are formed in the course of the early division of the previously fertilized ovum or to the abnormal fertilization of a little cell separated normally from the egg previous to the entrance of the spermatozoon.

However, this hypothesis can not be easily reconciled with the fact that the majority of embryomata appear in the germinal glands (ovaries and testicles), an observation which can be readily explained, if we assume that these embryomata are due to the parthenogenetic development of ova in the ovarian follicles. This is the more probable as I found that in about 10 per cent. of the ovaries of young guinea-pigs formations occur which can not very well otherwise be explained than as embryonal structures, placental[1] as well as embryonic in the stricter sense, developing abnormally from ova in the ovarian follicles and gradually being destroyed by the surrounding tissues. A previous fertilization could be excluded in these cases.

Moreover in the ovaries of various mammals one can not rarely observe ova in athretic (degenerating) follicles which show the first, somewhat irregular segmentations, and in the armadillo as many as eight cells may, according to H. H. Newman, be seen.[2]

While these observations explain satisfactorily the relatively frequent occurrence of embryomata in the germinal glands, they may also explain the embryomata found at other places, inasmuch as it is known that the germ cells migrate in various directions in the developing embryo, before they reach the germinal gland. In some cases however blastomeres (cells formed in the course of the early segmentation of the egg) may form the matrix of the tumors, inasmuch as it has been shown in certain

[1] The placenta is an organ of partly embryonic, partly maternal origin which is attached to the uterine wall and which transmits nourishment to the embryo.

[2] The first cleavages of ova in athretic follicles of mammalian ovaries previously described by various investigators and also by myself can not all be explained as maturation divisions which precede the segmentation; we may see occasionally ova which have divided into a number of segments, several or the majority of which may contain nuclei and at the same time observe in two segments mitotic figures or their remnants, the position and character of these segments making it extremely improbable that they represent polar bodies (Leo Loeb, *Archiv f. mikroscop. Anatomie*, Bd. 65, 1905).

classes of animals that a detached blastomere may reproduce the whole organism.

We have still to consider one very interesting kind of tumor, namely, the so-called chorionepithelioma malignum, which also owes its origin to irregularities in the activity of certain embryonic cells but which in some respects differs markedly from the other tumors considered so far. When the segmenting egg attaches itself to the uterine wall it does not only produce the embryo proper, but it gives also rise to certain cells which attach themselves to the uterine wall of the mother, and are mainly concerned in transferring food from the mother to the embryo, thus forming the embryonal placenta, the outer layer of which is called the chorion. These chorionic cells, which are therefore of embryonic origin, migrate already under normal conditions deeply into the uterine wall; they may even penetrate into maternal blood vessels and be carried to other parts of the body of the mother. Usually these chorionic wander cells perish after some time in the mother, but occasionally they give rise to very malignant tumors which destroy the uterine wall, and form metastases (L. Fraenkel, Marchand).

Just as these chorionepitheliomata may be produced from the fertilized egg cell developing in the uterine wall, so they may occasionally owe their origin to egg cells which develop into embryomata in the germinal glands and especially in the testicle. Here likewise chorionepitheliomata may develop. In the structures which I found in the ovaries of guinea-pigs the greater part of the dividing egg cells formed in contact with and probably under the influence of the ovarian tissue of the mother placental tissue and especially migrating cells which penetrated occasionally even into the walls of the neighboring blood vessels.

We have now analyzed some of the factors concerned in the origin of tumors found in childhood and early adult life. We recognized that they are caused partly by abnormalities of embryonic development, partly by parthenogenetic development of germ cells. At least these are two of the factors concerned in their origin—whatever additional factors may be found in the future. However, the greater number of all tumors, especially the large majority of the typical cancers found in later life, owe their origin to different causes. We can appreciate these causes best, if we consider certain special kinds of cancer which are somehow associated with certain kinds of occupation.

In general the character of the occupation does not seem to have a marked influence on the incidence of cancer, although it seems that cancer in certain callings (agricultural and forest workers, textile and wood workers, domestic servants) is somewhat more frequent than in others (miners, soldiers, factory workers in general). There are however certain occupations in which a direct connection exists between the

character of the work and the development of cancer. For instance in Röntgen ray technicians, especially in those who began their work, in the first years following the discovery of the rays, when the dangers connected with this occupation, the various precautions used at the present time were as yet unknown, gradually, often after many years of work, a painful condition of the skin arose, mainly on the hands and arms which were exposed to the rays, it became thickened, cracked, ulcers formed. The epithelium grew further down into the deeper tissues and slowly a carcinoma developed which later made metastases.[3] Approximately 70 cases are known where cancer thus developed, and in some cases it developed a considerable time after the exposure to the Roentgen rays had ceased.

Chimney sweeps develop relatively frequently cancer of the skin, especially of the scrotum, and it is interesting that this cancer may be found in young people. It has for instance been observed in a boy eight years old. The cause of this cancer is the irritation produced by soot. Those who are employed in the distillation of tar (especially of gas work tar) in the manufacturing of grease and briquettes are liable to develop cancer of the skin. Certain organic substances contained in tar and pitch cause the development of warts on the skin, which later break down and become transformed into cancers. In men employed in the manufacturing of aniline dyes, and certain other benzol derivatives, wartlike excrescences of the skin may appear; but especially interesting is the frequent appearance of cancers of the bladder in such cases. Each of the affected men had been in the dye works for 20 years or more. Evidently substances excreted through the kidneys exert in such cases an irritating action on the epithelium of the bladder.

There are some other occupations in which certain substances are the direct or indirect cause of the development of cancer. Just as Röntgen rays and certain chemicals, so may also light rays under certain conditions be the cause of cancer, especially in sailors, in whom sometimes the skin of that part of the body which is exposed to the light shows certain changes which lead gradually to the development of cancer. We notice also occasionally in old people and in rare cases even in young men in the face and on the hands, in parts therefore exposed to the action of the light rays, the development of multiple lesions, which in the course of time become transformed into carcinoma. There occurs furthermore in children a congenital skin disease, xeroderma pigmentosum, which develops usually into a carcinoma at places exposed to the light rays.

Very instructive is the cancer which is not rarely found in Kashmir among the carriers of the kangri, a little stove, which burns the skin on which it rests. Gradually cancers develop in the scars; the downgrowth

[3] *Cf.*, the careful microscopical studies of S. B. Wolbach.

of the epithelium is at first slow, but later metastases form in the lymph glands and a typical malignant carcinoma is now present (E. T. Nere).

Related processes—namely the gradual transformation of epithelium into cancerous growth—have been observed in cases of chronic ulceration of various kinds with incomplete healing of the epithelial surface as for instance in the case of the chronic ulcer of the leg, in the case of lupus, a tuberculous skin affection and in other similar conditions. Another class of cancers is produced directly or indirectly through the action of certain parasites, especially of certain worms (nematodes and trematodes). Thus in Egypt infection with bilharzia (*Distoma hæmatobium*) is relatively common. This trematod lives in the veins of the abdomen and lays its eggs in the mucosa of the bladder; they cause inflammation in the bladder, mostly in older persons, and later cancer develops in about 3½–5 per cent. of patients infected with bilharzia. In Bosnia, after bites of sandvipers, chronic ulcers without a tendency to heal may develop, and they may become carcinomatous. Also in other cancers a causal connection between a metazoan parasite and the tumor has been suggested in man, but this connection can not yet be considered as proven. Thus Askanazy found in a case of primary carcinoma of the liver *Opistorchis felineus,* while in Japan in similar cases a *Distoma* has been observed. In cases of chronic trichinosis carcinoma was found in organs which were situated in the neighborhood of the infected muscles. The presence of certain mites were noticed by Borrel in the case of mammary cancers and considered as its cause. It appears however that these latter parasites are just as frequently found in the non-cancerous breast as in cases of mammary cancer. The importance of nematodes as the cause of certain cancers in animals has been recently demonstrated, as we shall later explain more in detail. Of especial interest is the fact that while in the large majority of cancers caused by external irritation carcinoma developed, a few sarcomata have been observed in the skin under the influence of Röntgen rays, in the bladder in aniline dye workers and in persons infected with hilharzia.

We see then that under the influence of a considerable variety of agencies, cancer can develop in the human body and that in many cases cancer is preceded by the formation of warty or papillomatous excrescences and in other cases by long-continued ulceration, which in itself seems to be able to lead to the formation of cancer. At present we leave out of consideration the mechanism through which these agencies produce cancer, especially the question whether their action consists in a direct specific stimulation of the epithelial cells by the light and Röntgen rays, chemical substances and parasites or whether all these agencies act indirectly causing primarily ulceration, which later is followed by the development of cancer. We know indeed that chronic ulceration due to various causes may in itself lead to the development of cancer. Later we shall have occasion to return to this question.

We mentioned already that certain pathological conditions prepare the soil for the subsequent development of cancer, such as for instance lupus, chronic ulceration of the leg. But there are numerous other morbid conditions which stand in a certain causal relation to the growth of cancer. Gastric carcinoma originates in a considerable number of cases at the site of a previous ulcer of the stomach. Long-continued suppuration in the middle ear, fistules of various parts of the body may be followed by the development of cancer; so may certain affections, in which either certain parts of the skin or the mucosa are covered by plaques of horn, so-called (leukoplakia of the tongue and vulva, psoriasis). In the mammary gland chronic inflammation may lead to the subsequent development of cancer. Carcinoma may be preceded in the thyroid by goitre, in the liver, by chronic inflammation leading to an increase in fibrous tissue (cirrhosis), in the prostate by hypertrophy which is relatively common in old men. Inasmuch as certain conditions predisposing to cancer may be caused by syphilis, also syphilitic infection is indirectly one of the causes of cancer.

We mentioned previously that xeroderma pigmentosum, a congenital lesion of the skin, becomes usually cancerous. We furthermore know that certain at first benign tumors may later be transformed into cancers. Thus papillomata (polypus or cauliflower-like outgrowths) very often precede cancer of the small and large intestines or of the bladder. These papillomata are in the intestines frequently caused by preceding long-continued irritation; in certain cases however they are congenital. Pigmented moles of the skin if constantly irritated may be transformed into a pigmented cancer which is often very virulent.

At first benign tumor-like proliferations of the epithelium of the liver, mammary gland, ovaries, uterus, and especially glandular tumors (so-called adenomata) may later become transformed into carcinoma. As we have already mentioned, certain parts of teratomata at various places of the body are not rarely changed into carcinoma or sarcoma. The usually benign muscle tumors of the uterus (myomata) are in 6–10 per cent. of all the cases transformed into tumors resembling sarcomata, a change which does usually not take place before the patient has reached the fortieth year. In other cases, however, such myomata of the uterus are only the indirect cause of the development of cancer, the mucosa in their neighborhood becoming converted into carcinoma. Possibly the constant irritation caused through the pressure of the muscle tumors upon the epithelial lining of the organ may be responsible for this transformation. Furthermore, fat tumors (lipomata) may occasionally assume a malignant growth and become sarcomatous or soft, mucus-producing tumors (myxomata) which may be malignant and may metastasize.

Long-continued irritation is not always necessary but in certain

cases one single traumatism may undoubtedly cause the development of cancer. While, however, long-continued irritation usually leads to the formation of carcinoma, one single traumatism causes more frequently the development of sarcoma. Thus cases are known in which two months after a blow on the eye a sarcoma began to grow at the place of injury; in a child sixteen months old a sarcoma of the ciliary body of the eye developed after a blow; a sarcoma of the arm followed a stab wound at the site of injury. There are also cases on record in which a bone sarcoma developed after a fracture of the bone and after an extraction of a tooth the development of a cancer has been observed in the jaw. Also other than connective tissues may assume a rapid cancerous growth after an injury, as for instance the glia cells of the brain which are of the same origin as the nerve cells. Also carcinomata of the jaw originated subsequent to an extraction of a tooth. A carcinoma of the testis followed six weeks after an injury received from a horse.

In all these cases we have to distinguish between two possible results of the traumatism; the latter may either actually cause the new formation of a cancer or it may merely increase the rate of growth of a tumor that existed previous to the injury, which however only became apparent after the injury had increased the rapidity of the tumor growth. The latter condition existed for instance in the case of an embryoma of the testis which assumed a rapid growth after an injury, taking on the characteristic of a malignant tumor with subsequent formation of metastases.

We have now learned to know several sets of conditions which are either alone or in combination with other factors responsible for the occurrence of cancer, namely: (1) Irregularities of embryonic development. (2) Parthenogenetic development of ova. (3) The long-continued action of external stimuli, as for instance Röntgen and light rays, various substances acting chemically, long-continued ulceration and certain parasites. (4) Traumatism.

In certain of these cases we can state definitely that a combination of several factors had to come into play before carcinoma developed, for instance, in those cancers which follow xeroderma pigmentosum. Here a congenital lesion becomes converted under the influence of an external agency—namely, the light rays—into cancer. A pigmented mole is the result of some irregularity of embryonic development; it is present at the time of birth, and therefore a congenital lesion; mechanical stimuli cause its transformation into cancer.

We recognized that the majority of cancers of childhood differ in a definite way from the typical cancers of old age. We found reason to believe that certain embryonic irregularities are in part at least responsible for many cancers of childhood and early adult life. In the light of the data which we gave concerning the significance of external stimuli

in cancer, let us now briefly survey the typical cancers of old age. Such a review will demonstrate that for the production of the majority of all cancers the long-continued action of external stimuli is of the greatest importance. We stated that in civilized countries the large majority of human cancers occur in the alimentary and female generative organs, while the respiratory tract and kidney and ureter and the nervous system are much more rarely affected. The alimentary tract is the one through which the solid substances pass and which is therefore most easily exposed to constant irritation and possibly the action of certain parasites while through the respiratory and excretory tract (kidney, ureter) only gaseous substances or liquids pass; there is here therefore much less opportunity for long-continued irritation, and consequently less cancer. In the alimentary tract, those parts in which mainly fluid material is present, namely the small intestines, are least affected, while those in which especially solid material stagnates as in the stomach and rectum, cancer is most frequent. Cancer of the lip is frequently caused through the irritation of a pipe, cancer of the tongue and cheek is sometimes the result of constant irritation on the part of a defective tooth or prothesis. In the esophagus those places are the favorite seats where there is the greatest opportunity for irritation; in the stomach cancer is frequently found at the same site where gastric ulcer occurs most frequently and where the foodstuffs are apt to press against the pylorus in entering the small intestines. Certain chronic digestive disturbances characterized by a decrease or lack of digestive substances secreted by the stomach (achylia gastrica), in which there is therefore more irritation as a result of insufficient liquefaction of the intaken food, may also be followed by cancer. Irritation caused by the consumption of alcoholic beverages seems, in certain countries in which cancer of the stomach is more frequent in men than in women, to be one of the causes of gastric carcinoma. In the intestines cancer is frequently preceded by the formation of papillomata which again are in most cases the result of chronic irritation and inflammatory processes. Cancer of the gallbladder is more common in women, because women more than men are, as a result of certain habits, prone to suffer from gallstones, and gallstones cause a condition of constant irritation in the gallbladder. Carcinoma in the bile ducts has been observed to originate at a place where a gallstone was most likely to find obstruction in its passage into the intestines.

In the female generative organs cancer is most frequent in the cervix of the uterus, where, as the result of preceding labors, and of infection, tears and chronic inflammatory conditions are found to occur. In the mammary gland also cancer stands often in causal relation to preceding inflammatory conditions. In the ureter cancer has been found in connection with an incarcerated stone. In the respiratory tract cancer in

the nose may follow a disease, ozæna, while in the larynx cancer originates most frequently in the vocal chords which, through their situation and function, are most exposed to various external injurious influences.

This may suffice to prove the great significance of the continuous action of external stimuli in the production of the majority of the typical cancers of more advanced age.

While in general we can very well determine the dividing lines between the fields of the typical tumors caused through the action of external stimuli and those due to embryonic disturbances, there may in individual cases be some doubt. A number of pathologists extended it seems unduly the field of the tumors belonging to the latter class. They believed that microscopic studies of early tumors frequently demonstrated that they took their origin not from cells attached in a normal manner to the rest of the organs but from detached small fragments of organs. There would have been good reason to interpret the existence of islands of disconnected cells as an indication of imperfect embryonic development. Careful microscopic investigations show however that in the typical cancers of the stomach and intestines (Hauser, Versé)—with the possible exception of certain atypical so-called carcinoid tumors of the small intestines—and even in the multiple tumors of the skin (Janeway, Loeb and Sweek) the cancers originate through a direct downgrowth of the surface epithelium into the deeper tissues. Conditions preceding the development of carcinoma cause primarily an increased proliferative power of the epithelium which, as the result of this change, in the large majority of cases grows down into the deeper tissues and destroys them, but in some cases the resistance of the deeper tissues is so great that it successfully counteracts the invasion or dissolving power of the epithelium and the latter may instead of growing downwards be forced to grow towards the outside of the skin, as we could observe in a case of multiple carcinoma of the skin. This increased proliferative and infiltrative power of the epithelium is therefore the principal characteristic of cancer.

This change in the proliferative power of the epithelium may be accompanied by a change in the structure of the affected cells, which appear often less differentiated. This loss in the complexity of proliferating cancerous cells has been called anaplasia. In other cases, however, this morphological change in the proliferating cells may be entirely absent, as for instance in some beginning Röntgen ray cancers.

Still furthergoing structural modifications of the proliferating cells may take place in the secondary (metastatic) growths, although on the whole metastases repeat more or less the structure of the primary tumor. Thus we may in the case of a primary carcinoma of the liver find metastases in which the tumor cells continue to produce bile just as the normal liver cells do, and especially primary as well as metastatic tumors

of the thyroid may be hardly distinguishable from the normal tissue from which they are derived.

Microscopic studies of early stages of cancers showed furthermore that in many cases the growth starts at one well-defined rather limited area of the affected tissue; and that all the tumor masses developing subsequently are derived from the relatively few cells which were originally seen to proliferate. In other cases, however, the tumor growth originates at several neighboring places simultaneously. And in still other cases a certain tissue may, over a wide area of the body and even at distant places, give rise to cancer formation simultaneously or successively. In such cases we may assume that some change predisposing to the development of cancer has taken place in the affected tissue, and that relatively slight external stimuli, as for instance an injury, effect of light, are sufficient to call forth the actual cancerous proliferation.

Usually the proliferating cancer cells do not infect neighboring cells with which they may come in contact during their proliferation. While as a rule the neighboring normal cells do not become cancerous in contact with cancer cells, this does not hold good generally; and as we shall see later the study of animal cancer has shown that such transformations may take place under certain conditions.

The careful microscopic studies of many pathologists (among American investigators we might cite among many others: Councilman, Mallory, Ewing, LeCount, Warthin, Wilson and MacCallum) have contributed many important and interesting facts concerning the structure of various tumors, their resemblance to and deviations from the structure of normal organs from which they are derived and such studies formed the basis of a more detailed classification of tumors (von Hansemann, Adami). We have learned that each organ or tissue gives rise to specific tumors which not only differ in structure and metabolism, but also in their proliferative and metastasizing energy. It will, however, not be necessary to discuss these differences more in detail on this occasion.

Before leaving the problem of human cancer we will briefly consider what part heredity and microorganisms play as the cause of tumors in man.

Heredity is undoubtedly a factor in those cancers which develop occasionally in cases of xeroderma pigmentosum or from pigmented moles. We know that here the conditions preceding cancer are hereditary and therefore cancer itself is indirectly hereditary. We furthermore know that a certain class of cancers originates on the basis of embryonic malformations, and inasmuch as these are under certain—as yet not well defined—conditions hereditary, we may assume that certain cancers belonging to this class are also hereditary. There is indeed some evidence which points to this conclusion. There is for instance a case known in which both the mother and her one and one fourth years old

child became affected by glioma of the retina (a tumor originating in modified nerve cells of the eye). In another case a twenty-one-year-old man had 17 osteomata (tumors consisting of bone tissue) symmetrically arranged and his father had similar tumors. It is furthermore known that in certain cases polyps of the intestines are congenital and occur in several members of the same family. On the basis of such polyps cancer not infrequently develops. We have therefore reason to believe that heredity plays a rôle in a certain number of that type of cancers in which flaws in embryonic development are a factor.

In the case of the typical cancers of later life in the causation of which as we stated external stimuli play such a prominent part, it is very much more difficult to determine the significance of heredity. We know that the frequency of cancer varies very much in different races; but we have also seen that we can as yet not be certain how much this difference is due to factors inherent in the race (heredity) and how much it is due to variations in the mode of living and to preceding inflammatory conditions in the affected parts of the body. The ordinary methods of vital statistics which almost exclusively have so far been applied in cancer seem to show that in about 14–18 per cent. of persons affected with cancer other cases of cancer occurred in the family. Now it is doubtful whether this incidence is greater than should be expected according to the law of probabilities. Even extensive statistical studies of this character can evidently not solve the problem. We must rather turn to intensive studies of the incidence of cancer in various families for a solution. There are indeed already some data available which seem to indicate the existence of a hereditary factor also in the causation of the typical cancers of more advanced age. In certain families, as for instance one reported by Broca, the incidence of cancer has been extraordinarily high. A. C. Garmann found that in a certain district of Norway, the population could approximately be divided into 20 distinct families, and 72.8 per cent. of all cases of cancer occurred in a single one of these 20 families. J. Levin has begun to use the statistical material collected at the Eugenics Record Office of the Carnegie Institution in Cold Spring Harbor for such intensive statistical studies. In one family on which he has reported recently he found, that a fraternity in which one or more members suffer from cancer, usually shows in a previous generation a cancerous member either on the paternal or maternal side or on both sides. It may be expected that a continuation of such studies will decide definitely the problem as to the significance of heredity in human cancer. As we shall see later, in the case of animal cancer the great importance of heredity has recently been established.

Especially since the discoveries of various microorganisms as the cause of certain diseases, the possibility was always in the minds of investigators, that also in cancer besides the conditions enumerated micro-

organisms might be responsible for the cancerous cell proliferation. We must of course remember that our present knowledge of the factors underlying cancer was only gradually acquired; furthermore that certain experiences concerning animal cancer which we shall discuss later, suggested microorganisms as the direct stimulating agencies while the other factors which we analyzed so far would represent merely indirect causes, making the infection with microorganisms more easy. We know indeed that to a certain extent microorganisms can call forth cell proliferation. Thus the tubercle bacillus may cause a limited growth of connective tissue and as especially Borrel has pointed out the organisms causing smallpox and vaccinia may even produce a slight proliferation of the infected epithelium. But in all those cases the proliferation soon ceases and toxic substances produced by bacteria lead usually soon to the death of a great part of the newly-formed cells.

Based on such considerations many attempts have been made to prove the constant presence of certain parasitic microorganisms in human cancer. Under the microscope it is possible to recognize in cancer cells certain inclusions which are usually absent in normal tissues and a number of investigators claimed such included bodies definitely as protozoa (among others, Thoma, Sjoebring, Leyden, Gaylord and Eisen). Even the life cycle of these protozoa was apparently determined by some of these authors. It could, however, be shown that similar cell inclusions may originate otherwise and did in all probability therefore not represent protozoa. Also bacteria (Doyon), mucor (Schmidt), chytridiaceæ (Behla) and other microorganisms were held responsible. Others (Sanfelice, Leopold) believed yeast-like organisms to be frequently demonstrable in human cancer; they cultivated some yeasts in culture media and by injecting the organisms into animals believed to have reproduced the disease. Careful studies by many investigators, however, could not confirm these interpretations. In the case of yeasts it has for instance been shown that although they occasionally occur in cancers, they are on the whole rare and do not reproduce the disease if injected into animals (Busse, Nichols, Loeb, Moore and Fleisher). They act in the body in a similar manner as inert foreign bodies, and we found a yeast which we isolated from a sarcoma to lead, after intravenous injections, to the death of the animal through occlusion of the kidney tubules, without ever producing cancer.

These persistent claims of the discovery of a microorganism as the cause of cancer which could in no case be substantiated led in the case of many pathologists, especially of those mainly interested in the careful study of the structure of pathological tissues, to a reaction which induced them to deny the possible importance of microorganisms in the causation of cancer; they were inclined to hold on the whole the factors already established as sufficient to explain the origin of cancer. On the

other hand, a number, especially of experimental investigators, without being able to accept as valid any of the claims as to the discovery of a microorganism as the cause of human cancer, always pointed out the possibility that microorganisms might at least in a certain number, perhaps even in a majority of cases, be a factor in the production of cancer and tried to find new experimental means to approach these problems; accordingly on various occasions we pointed out the possibility that ultra-microscopic, perhaps intracellular, microorganisms might induce body cells, under certain conditions, to proliferate in such a manner that cancer resulted. However, in no case of human cancer has the causative significance of a microorganism so far been proven. We shall see later on that in a certain kind of animal cancer this proof has recently been supplied by Peyton Rous.

PSYCHOLOGY: SCIENCE OR TECHNOLOGY?

By E. B. TITCHENER

PSYCHOLOGY has, of recent years, been exhorted to be practical, praised for its willingness to be practical, blamed for its unwillingness to be practical. "A kind of psychology which is needed is that of every-day people." "Psychology is ceasing to be a purely academic science and is now willing to study questions dealing with every-day life." "Psychology as it is being taught and investigated deals with matters of no concern, or of too abstract a nature, for practise." "The normal psychologist has been forced out of his academic reserve." A psychology is needed "which is aimed at practical ends," "a psychology which works and lives rather than a psychology easy to teach or easy to write," a psychology of a "matter-of-fact type," which adopts "the common-sense attitude," a psychology whose problems "really go at the causal relationships vital to the student, vital to any layman who wants to know what psychology is and does, vital to the physician,"—in a word, a truly "dynamic" psychology. The demand, as these few quotations show, far exceeds the supply; exhortation and blame are more strongly in evidence than encouragement and praise.

If, now, such amenities meant simply that there is a family quarrel among psychologists, or if the attack upon theory and the call to practise were confined to psychology alone, then discussion and reply would find their proper place in some technically psychological journal. It seems, however, to a lay reader of scientific magazines, that the stir in and about psychology is typical of what is just now going on in many other fields of scientific work, and that the issue between theory and practise has been raised in many quarters. That would, of itself, be good ground for appeal to a general scientific audience; but the present writer has a second reason for bringing discussion into the open. He believes that, so far as the matter may be argued, so far (that is to say) as we leave out of account temperamental differences and idiosyncrasies which are beyond the reach of argument, hostilities are in the main kept up through the neglect of a very elementary distinction, the distinction of Science and Technology; and he believes that, if that distinction is regarded, there may be an end of railing accusation and a new birth of what theory and practise both alike require—serious and well-weighed criticism. It is true that the mere expression of this belief may defeat his purpose: the practically-minded reader may refuse to read further;

for the practical man is nothing if not outspoken in his dislike of hair-splitting distinctions and formal definitions. Let it then be said, at once, that there shall be no formal definition in the present paper, and that there shall be as many loose ends left as the most matter-of-fact common sense can desire. The distinction to be drawn is, in truth, elementary, and the drawing will here be done in the grossest way.

What follows, therefore, is an attempt at an *eirenicon;* and it begins at the beginning, with the question—What do we mean by science?

I

We are still told, in text-books and scientific addresses, that the various sciences represent various *departments* of knowledge. The territory of science, that is to say, is conceived of as parcelled out among the separate sciences, very much as a continent is mapped out into a number of adjoining countries. If the tale of the sciences were complete, the whole map would be variously colored; since, however, there are "gaps" in our knowledge, the map shows blank spaces, unexplored regions to which the methods of science have not yet attained. "The gaps are being filled; we are no longer isolated, but are working side by side on adjacent areas which are inseparably connected;" so said the president of the recent Medical Congress; and the figure was probably as familiar to his hearers as it fell naturally from his own lips.

A figure of this sort, however uncritically it may afterwards be employed, is always suggested in the first instance by some aspect of the facts; and in the present case the suggestion is not only obvious, but is also continually renewed. Few of us would hesitate to say, off-hand, that the "tree" belongs to the province of botany, and the "inclined plane" to the province of physics. The things that we find in our surroundings fall, as we say, into groups, as subject-matter of this or that science; and the sorting or classifying of things, which is perhaps the earliest form of man's intellectual mastery of his world, still suffices for practical purposes and may, as our quotation shows, prove to be sufficient also in scientific contexts. That figure, nevertheless, together with the principle of classification which it implies, must now be discarded; the sciences can not be looked upon as departments of knowledge, adjoining and mutually exclusive, each one covering and exhausting a certain tract or region of experience, and each one concerned with a separate kind of subject-matter. The tree, we said, is placed by our ordinary thinking in the province of botany; yet this same tree may be considered from the points of view of taxonomy, ecology, distribution, morphology, physiology; it may be discussed by chemistry, or by general biology; and finally as look and feel it belongs, with all the looks and feels, to psychology. The inclined plane is in a like ambiguous position. These are, no doubt, trivial examples; but

they serve to bring out the fact that one and the same item of human experience may enter, as part of their subject-matter, into a large number of sciences; whence it follows that the sciences themselves can not be distinguished, in any final accounting, by the specific character of the "objects" with which they deal.

What in fact differentiates science from science is, as an earlier sentence has hinted, something that we may term objectively *point of view* and subjectively *attitude*. Giving up the figure of the map, one might conceive of the world of experience as contained in a great circle, and of scientific men as viewing this world from various stations upon the periphery. There are then, in theory, as many possible sciences as there are distinguishable points of view about the circle. Every science seeks to view the whole world of experience from its particular station; and every science deals, from that station again, with identically the same subject-matter, namely, with human experience. The separate sciences are, therefore, not at all like the countries on a map; they are rather like the successive chapters of a book which discusses a complex topic from various points of view. In this sense, they overlap; they are mutually complementary; no one of them in truth exhausts experience or completely describes the common subject-matter, though each one, if ideally complete, would exhaust some aspect of experience.

It is, then, from some such figure as that of the circle and the men around it that a classification of the sciences must start. We must add, however, both for the sake of clear thinking and to forestall criticism, that the figure does not "work"—it loses its regular outline and at the same time grows more complex—when we come down to details. Thus, to say that the world of experience is a circle is to say that all the sciences, at least in their ideal completion, are coextensive; and to say that the sciences are views of the world obtained from standpoints about the circle is to say that all the separate sciences are, as sciences, coequal; and both of these statements may fairly be challenged. Such matters of detail, difficulties as they are to those who attempt a classification of the sciences,[1] need not however detain us; the fundamental idea of our figure is sound. The figure itself helps us even a little further; for the question how it comes about that men can take up their stations around the circle, and so view human experience as if from without, is evidently the problem of a theory of knowledge, of logic in the broader sense; and the question of the essential nature of the whole, of experience viewed and experiencers viewing, is as evidently the problem of a metaphysics.

[1] Flint's essay on classification in "Philosophy as Scientia scientiarum" is of very uneven merit, but contains much valid criticism and is useful as a general survey of the field. Flint remarks that "the fundamental sciences are not classed according to individual objects. Every object is complex and can only be fully explained by the concurrent application of various sciences."

With the latter discipline, science has nothing to do; with the former, as we shall soon see, it has a great deal.

II

If, however, there are certain difficulties which we may, in the present connection, rightly pass over, there is a further question which can not thus be avoided. We are bound to characterize more closely the *scientific* attitude, or the *scientific* point of view. Human experience may be brought together in other than scientific ways; and while we still need not seek for formal definition or final classification, we must try at least to differentiate science from the appreciating disciplines and from what we have called technology. We must find distinguishing adjectives for the attitude itself, for the method which it implies, and for the problem which it discovers.

The history of science leaves no doubt of the answer to be given to this threefold question. The attitude of science, to begin with that, is before all things a *disinterested* attitude: witness the rise and growth of astronomy, of chemistry, of physiology. Until mankind has learned to take experience in serious earnest "for its own sake," to subordinate personal ends to the pursuit of truth, there is no science, but only something which at its worst is quackery and pseudo-science, at its best common sense and rule of thumb; and conversely, so soon as a man starts out to examine some aspect of experience as if it were for itself important and knowledge of it were intrinsically desirable, so soon does the germ of a science appear. For the race, the learning of this lesson was difficult enough; and so, in the large, the negative form of the adjective—dis-interested—may be justified; science sets aside the oldest and what we might consider the most natural interests of man. For the individual, on the other hand, a positive term would be more suitable. The curiosity or, as Helmholtz named it, the *Wissensdrang* which marks the scientific temperament renders the "disinterested" work of science the most interesting thing, as Helmholtz also said, that its possessor can find to do. The adjective must be kept, partly for its historical associations, and partly because the writer can not think of a positive word that should replace it; but it must be understood, when the worker in science, the scientifically-minded individual is in question, as meaning self-fulfilment rather than self-renunciation. Otherwise, science would never have had its martyrs.

The scientific attitude, then, is disinterested; the point of view of science is one that shall reveal the unvarnished fact; so much we are plainly taught by the history of science. We gather from the same source that the method of science is *observation*. All the "facts" of science are gained by a disinterested observation; sometimes, by an

unaided observation; more often, since the conditions are complex, by the roundabout way—which is still observation—of experiment and measurement. We need not pause to illustrate, or to cite the authorities; the conclusion is generally accepted; and every piece of apparatus in our laboratories shows as an instrument for the control or the extension or the refinement of observation.

It is, perhaps, less apparent that all the problems of science may be summed up in the single problem of *analysis;* that the task which lies before the man of science, in his character as scientific, is always the analysis—under which is included, of course, that synthesis which is a test of analysis—of some complex object or complex situation. The reduction of a compound to its elements, the differentiation of factors, the establishment of correlations among the components of a given whole,—these are the things that the scientific investigator finds himself doing. True, we shrink a little from running all men of science into the same mold; we individualize them; we think of Newton as wielding "the ponderous instrument of synthesis," of Darwin as "working on true Baconian principles, and without any theory collecting facts on a wholesale scale." We are right in thus individualizing; for not only is the man of science something more than a scientific machine, but science itself is also (as we are to see in a moment) something more than what we have so far made it out to be. The witness of history is, nevertheless, straightforward enough; what Newton and Darwin, as scientific men, had before all things to do was to analyze, and to analyze again, and again to analyze. To be scientifically active is disinterestedly to apply the method of observation to the task of analysis.

III

Our three adjectives are thus given: disinterested, observational, analytical. Taken together, they characterize the scientific attitude with sufficient accuracy for the purposes of this essay. They do not, however, cover the full meaning of "science" as that word is ordinarily used and understood. When we speak of science, we mean, not an assemblage of observed facts, the direct results of analysis, but rather an organized and systematized body of knowledge, a closed and self-contained whole. That every science, every transcription of the world from a scientific point of view, should yield a system, as if there were of necessity some immanent principle of order which the facts illustrate and to which they conform, is of course an assumption, and an assumption that we might find curious were it not so familiar. Originating perhaps in physics, supported by the belief in the general uniformity of nature, and favored by the tendency to regard the sciences as departments of knowledge, and therefore as concerned with divisions of the cosmic mechanism, it has been accepted, more or less consciously, by

biology and psychology. Whether the acceptance was wise, and whether economy of thought may not be paid for too dearly, are questions beside our immediate point. What we have to note is this: that to systematize the facts of science, by any principle immanent or external, is to bring logic to bear upon them, to arrange them in the light of those logical laws which the experience of the race has tested and found secure, and which therefore form the stock-in-trade of a beginning theory of knowledge. We proceed, says Bacon, "by observing or by meditating on facts"; "to the formation of a science," writes Whewell, "two things are requisite,—Facts and Ideas; observation of Things without, and an inward effort of Thought"; and Huxley demands for a science "scientific observation" and "scientific reasoning." Science, that is to say, in the meaning of a scientific system, is the outcome of scientific activity ordered by logic.

It is only, be it remarked, when we thus consider science as a system, that we can at all subscribe to Huxley's definition of science as "organized" or "perfected common sense." Scientific activity is almost the antipodes of common sense. For science is disinterested, and common sense is self-centered; science is observational, while "there is not one person in a hundred who can describe the commonest occurrence with even an approach to accuracy"; and science is analytical, while common sense, as Huxley shows by reference to "the natural object Water," is content with gross appearance and total function. Common sense is the average man's intellectual *modus vivendi;* and the one practicable bridge that connects it with science is the bridge of logic; the average man is, in his own way, a very Aristotle. Were that bridge to fall, the definition would be impossible; we should have merely the occasional instances in which the points of view of science and of common sense coincide,—limiting cases, too few to provide even stepping-stones from the one to the other.

Science, therefore, may mean two things, scientific activity and the scientific system; and this twofold meaning is a fertile source of confusion. There is always the danger, for instance, that logic, which is a good servant, become the master,—as it does when Pearson tells us that the goal of science is "nothing short of a complete interpretation of the universe." Science, as scientific activity, aims at no goal; even the phrase "pursuit of truth," useful and inevitable as it may be, may also be misleading; science is, in strictness, only self-directed upon an endless task. So the result of scientific activity is not an interpretation, in any pregnant sense of that term, but only a transcription of the world of human experience as it appears from a certain point of view. Science, in Pearson's formula, thus stands for the system of science; and the system in turn is made to stand, not only for the outcome of scientific activity as worked over by an accepted theory of knowledge,

but also for a special theory of knowledge under which the outcome of scientific activity has, to Pearson's satisfaction, been subsumed; logic has become the master. The same logic is, none the less, an indispensable servant. We may set aside the whole business of making systems: yet we shall never plan an investigation, or carry out a research, or present our results to our fellow workers, without calling in the aid of logic. Scientific activity and logical activity are always and everywhere intermingled; a book like Jevons' "Principles of Science" is, in the nature of the case, very largely a logic; it is logic that adds the subjunctive and imperative moods to Poincaré's scientific indicative. And if, for all these reasons, the clean distinction of the two activities is intrinsically difficult, it becomes the more so in the concrete case, seeing that the specialist in science is likely to employ a special logic, the logic of his special point of view and of the "facts" which that point of view discloses, so that he seems presently to work by "intuition" and the activities appear to have been blended rather than intermixed.

Still, the activities are in themselves different; and in the main, in the broad, our thinking must recognize their difference. We are, again, not to split hairs, or to attempt any hard and fast distinction. But let the reader take up a text-book—that very practical thing—in some one of the newer sciences; let him go through it, pencil in hand; and let him mark, as he reads, the passages that are derived from scientific activity on the writer's part and the passages that are logical. Sometimes, of course, he will be in doubt; and the doubtful passages, since we are making but a rough and ready test, may be left unmarked. They will occur most often in the early chapters of the book,—partly because the introductory chapters are likely to be of a general character, partly because the reader is not yet skilled to distinguish the one sort of writing from the other. As more and more pages are turned, the marking becomes easier, more prompt and more certain; the reader feels that he has the key to the cryptogram; and the result is instructive enough to warrant the few hours that have been given to the task.

IV

We may sum up these paragraphs in the statement that science is defined by its point of view. The scientific man looks out upon experience from a certain standpoint; sees and can see his world only under one aspect; and by this attitude, which he has taken up toward experience, is limited to a particular type of method and to a particular type of problem. To invite him from his "academic reserve," or to demand that he interest himself in "practical ends," is simply to bid him cease from scientific activity. The scientific man, again, is logical, just as the historian or the jurist is logical; but logic is not science; and within science the facts of observation take precedence, and logical

methods are secondary. To say that science leads to, or suggests, some general 'interpretation' of things, is to say what may or may not be true; but the saying, in either case, transcends science itself and changes the man of science into the philosopher. It must, indeed, be acknowledged that science, despite the immensity of its scope and the multitudinous variety of its subject-matter, confines its followers within relatively narrow limits; the shadow of the three adjectives is always upon them; and it is just because science is thus narrower than life that the man of science, unless he be of a certain temperament, is tempted to transgress the limits, and to betake himself in the long run to philosophy —or to spiritism.

V

Over against science, now, stands what we have called technology. In a certain restricted meaning, this term—which we have so far employed without comment—is familiar enough; the greatly extended meaning which it is here to receive must be justified by the sequel. The word is used henceforth to cover, in the broadest way, the activities that are ordinarily and misleadingly referred to as "applied science"; such things, that is to say, as engineering and medicine, in all their branches; such things as scientific agriculture, and domestic science, and school hygiene, and industrial chemistry, and eugenics. All these disciplines have a common character, by which they are set off from science; for, if science is defined by its point of view, technology (in the new and wider sense) is defined by its end or goal. Technology thus has its own narrowness; it is held down to the pursuit of some particular practical end; but this narrowness is different from the limitation of science. The technologist may change his point of view as often as he likes; he will use any method that promises to be serviceable; he will attack any problem that rises in his path. The result is that a "system" of technology is likely to appear to the man of science a mixed medley of more or less unrelated knowledge, and that a pure science is likely to appear to the technologist an example of fine-spun and quite needless consistency. A text-book of engineering will range from sections on pure mathematics and pure mechanics to practical directions for the setting-up of instruments and the reading of indicator cards; and a system of medicine, in the same way, will skip from theory to practise and from practise back again to theory within the boundaries of a single paragraph.[2]

[2] Consider, for example, what is probably one of the last attempts to treat the whole of mechanical engineering in a single volume, Lineham's "Text-book" (1902); read and abstract Ch. IX., On Energy and the Transmission of Power to Machines: or consult any chapter of such a work as Thompson's "Practical Medicine." Reading of this sort is instructive, not only to the man of science, but also to the technologist whose interests lie in other fields than those covered by the book under examination. When the engineer or the physician has been shown that the eugenist derives his materials from pathology and medicine, from

The authors are entirely in the right; their readers are physicians and engineers, and not physiologists and physicists; their subject-matter is held together and unified by a practical aim, and not by an initial point of view; it is unfair to judge them by the standards of science. A text-book of physics or of physiology, on the other hand, is—as we have seen—a transcription of the world of experience from a particular standpoint, which is deliberately adopted at the outset and deliberately maintained to the end; no item of experience that is not visible from this standpoint can properly get into it; and it is unfair to judge it by the needs and aims of a technology. All human activities have their limitations: and if the technologist is less clearly conscious of the restriction laid upon him by his practical end, and the man of science feels more keenly the narrowing of his universe by the scientific point of view,—the rule is certainly not without exceptions; but we may grant the tendency,—that is due partly to the greater outward diversity of the technological career, and partly to the more rigorous training in logic that scientific investigation affords and demands. The technologist never, to be sure, handles experience in its totality, but he deals with individual cases, and so comes nearer to the concrete than his scientific colleague; and he may, moreover, change from the practical to the scientific or the appreciative attitude without any great fear of leaving his last; his interests are thus diversified. The man of science, constantly applying the principles of logic, and constantly on his guard against the encroachment of logical theory upon the facts of observation, is forced to be self-critical, and so comes nearer to a true perspective.[3]

physical and social anthropology and ethnology, from statistics, from general biology, zoology, botany, thremmatology, from psychology and psychophysics, from ethics, economics, sociology,—then he is the more apt to realize from how many and how various sources his own discipline is sprung.

[3] A good illustration of what is here meant is furnished by the current use of the word "dynamic," to which attention has been called in the introduction. Occasionally, "dynamic" as opposed to "static" seems to mean simply temporal as opposed to spatial, or to imply a longitudinal section of experience as opposed to a cross-section. Ordinarily, however, as the term is used in psychiatry and "applied psychology," it seems to go back to an exploded theory of causation, or even behind causation to animism; it seems to imply a driving power, or motive force, or an interplay of effective powers and forces, such as is wholly unfamiliar to modern science. It has become, so far as the writer can make out, a sort of watchword, expressive of emotion rather than of thought; at any rate, he knows of no attempt to define it. Again, one of our leading psychiatrists warns the "professional psychologist . . . [to] come to the hospital clinic. He must imitate the geologist and leave his academic shades and seek his material for study where it is to be found. It is in pathologic conditions of the mind that he will find his true field of research." All honor to the clinic!—but has then the crust of our earth gone moldy, and are all geological formations diseased?

Different, however, as science and technology may be, they are also closely related. Technology draws on many other than scientific sources; it draws upon common sense, upon existing technologies, upon pre-scientific practise; but it draws continually upon science. Science, in its turn, is furthered by technology. The pursuit of a practical end often reveals some defect of theoretical knowledge; and the repairing of this defect, itself a contribution to science, may perform more than it promised, may in fact open up some wholly new field of scientific enquiry. That is the nature of the relation; and at first sight the advantage seems to lie with technology; for if the technologist needs the aid of science, he also appears capable of supplying for himself the science that he needs; he has only, for a little while, to shift his attitude, and the science is forthcoming. Where, then, would be the loss if pure science, with its "unreal" and "abstract" concerns, went by the board, and we all became practical together?

In answer to this question there are two things to be said. We must remember, in the first place, that every technology is limited by its end. When a technological need suggests a problem in pure science, the suggestion bears directly upon the need out of which it arises, and upon that need only; when the need is satisfied, there is no further sanction, within the technology, for purely scientific work. If, in other words, the progress of science were made dependent upon the progress of technology, and theory were never invoked save for the sake of practise,—if such a state of things were conceivable,—then our scientific knowledge would perforce remain scrappy and partial, so scrappy and so partial that a halt would ultimately be called to the advance of technology itself. An all-embracing technology, starting out with things as they are today, would no doubt be able to maintain itself for a relatively long time; theory is, in general, so far ahead of practise that, though science now stopped short, technological advance would long be possible. It is this fact, of course, which gives a plausible coloring to the demand that science leave its heights and come down among "every-day people," and that the man of science, instead of adding to his store of observed facts, use his scientific capital for "practical" and "vital" purposes. Sooner or later, however, the capital would be exhausted; sooner or later, progress would slow down to stagnation; the needs of technology, occasional needs of a circumscribed activity, would not suffice in the long run for the advancement of science. And then there is the other side of the shield! Technology, we said, draws from many sources, but is continually drawing upon science; each separate technology, we may here add, upon many sciences. Now if any induction from the history of human achievement is secure, it is surely this: that there is nothing in science so abstract, or so remote from matter of fact, or so indifferent to common sense, that it may not, some day or other, prove of service to

a technology; and since this is the case, it is really to the interest even of the most practical man that scientific activity should be conserved and encouraged.[4]

A second consideration brings us by a different road to the same conclusion. The close relationship that we have shown to hold between science and technology is the relationship that holds in a scientific age,—at a time when science has won to recognition, is cultivated internationally, is widely popularized. In such an age, it is natural, as it is also the best policy, for technology to draw upon science. Technological activity, however, is a very complicated affair; and it may be doubted whether technology, if left wholly to itself, would turn instinctively even to the best scientific systems available; still more that it would supply for itself, by arduous and unaccustomed work, the knowledge that those systems fail to furnish. The tendency would rather be (and this is no dispraise to the technologist, who may never lose sight of his practical end) to fall back upon past science, upon science that was already more or less familiar, or to extend technological activity by purely technological means. Indeed, this tendency may be observed at the present day. The leader of a reform-movement in psychiatry, which has found critics and adherents over the whole civilized world, expressly bases his teaching upon psychology; but the psychology which he has in part adopted, in part worked out anew,—and which he appears to find entirely adequate to his technological needs,—is in essentials the psychology of a past generation. The writer takes this illustration from the field which is most familiar to him; the reader will be able to supply others from his own experience. The moral of such things is surely plain: that the technologist, for the very sake of his technology, needs the stimulus, the criticism and the assistance, of the man of science. Practical work tends, always and everywhere, to become routine work; routine tends toward conservatism, toward the defence of the old and the avoidance of the new; and conservatism ensures social stability. But if our ideal of society is a progressive equilibration, rather than the mere inertia of routine, then the conservatism of practical work must be tempered by the radicalism of science.

VI

It is difficult, in writing upon a disputed question, not to give the impression that one is trying to disparage one's opponents. Yet the writer has no desire, despite the many hard things that technologists have said of the science with which he is most nearly concerned, to attempt any sort of disparagement of technology. Science and tech-

[4] "The fact is"—so Clifford puts the matter—"that the most useful parts of science have been investigated for the sake of truth, and not for their usefulness."

nology are, first of all, different. Science is defined by its point of view; the man of science takes his stand at the handle of the fan, and looks out along the sticks to an undefined periphery. Technology is defined by its practical end; the technologist, moving over the periphery, chooses and shapes the sticks which are to meet at the pivot that he has always held in view. The advice to "let the facts lead us where they will, over the hills and dales of physiology, into the deep borings of anatomy, or upward into the ethereal reaches of psychology" is admirable advice to offer the technologist; but its phrasing shows that it would be fatal if accepted by the man of science. For suppose that the man of science should accept it! Then the technologist, asking physiology for a detail of the landscape, might receive a sample of ore; or asking anatomy for the dip of the strata, might receive a cloud-photograph: things well enough in their own place but, out of place, turning his ignorance into sheer confusion. It is only in so far as he can rely upon the physiologist to keep his physiological point of view, and the psychologist his psychological, that the technologist is able to move freely from the one science to the other in pursuit of his practical end.

It follows from this primary difference that no technology is properly characterized as the application of a special science. Every technology is itself a special discipline, indebted (to be sure) to many sciences and to many other sources than science, but adding matter and method of its own, and rounding up all that it handles into a single whole. It is therefore no more in order to speak to-day, say, of an "applied psychology," than it would be to call engineering by its older name of "applied mechanics"; and the sooner we recognize that, in this particular sense, technology is independent of science, that the technologist lives and moves in a world of his own, has his own problems and methods, is charged with a special message to his generation, the sooner shall we exchange our present bickering for the harmony that we desire.

Science and technology are, in the second place, closely related; the nature of the relationship has been sketched in preceding paragraphs. If we look at this relation from without, from the side of maintenance and material aids, then the advantage lies with technology, and science is the beneficiary. The scientific man, accordingly, should rejoice at every technological advance, seeing that it ensures by just so much the material future of science. "How many men," asked Kepler in the old time, "how many men would be able to make astronomy their business, if men did not cherish the hope to read the future in the skies?"—and, with change of terms, the story is told again of us moderns. If, contrariwise, we look at the relation from within, then, as this paper has tried to show, technology appears as the beneficiary of science. The technologist should accordingly rejoice at every scientific advance, seeing that it means just so much more of observed fact which he may some

day utilize in his practise. To slight the "leisure-class problems of true science" in the supposed interest of activities which "earn their bread in terms of usefulness for the questions of life" is really to mistake that interest, and to wound technology in the house of its friends.

Lastly, science and technology are alike in their free recourse to the established laws and approved methods of logic. Science is, on the whole, more rigorous than technology in this logical regard; not through any superior virtue in the man of science, but simply because the technologist, in the nature of the case, is a logical opportunist, working for results and towards a practical end, and therefore content to work in a logical twilight so long as results are forthcoming and progress can be reported. That the technologist should, on occasion, betray impatience with the stricter canons of scientific procedure is only natural. That the student of science should stir in his own defence must also be expected: how great, after all, are the benefits that science has conferred upon humanity! What we may hope for is that men of intelligence and sound training, after they have been distributed by temperament or circumstance to scientific and technological activities, may still so far keep in touch that each understands the other's limitations and sympathizes with the other's ideals.

THE ILLINOIS SYSTEM OF PERMANENT FERTILITY

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I HAVE been invited to write upon the Illinois system of permanent fertility; but I wish to state in the beginning that, in complying with this request, I am speaking in a representative capacity. Many have contributed to the development of this system, including both able investigators in other states and countries, my own colleagues in the investigation of Illinois soils, and the truly scientific farmers of this state, some of whom have kept their own farm practise so close up to the work of the experiment stations as to exert great influence upon the adoption of systems of permanent fertility.

It is more than fifty years since Liebig wrote the following words:

> Agriculture is, of all industrial pursuits, the richest in facts, and the poorest in their comprehension. Facts are like grains of sand which are moved by the wind, but principles are the same grains cemented into rocks.

An important part of the work performed in Illinois has consisted in assembling the facts the world affords and cementing these into concrete forms which serve as a firm foundation upon which to build systems of permanent agriculture.

The main problem of permanent fertility is simple. It consists, in a word, in making sure that every essential element of plant food is continuously provided to meet the needs of maximum crops; and, of course, any elements which are not so provided by nature must be provided by man. The whole subject has been greatly and unnecessarily complicated, not only by erroneous theories commonly held by farmers and something advocated by unscientific "scientists" holding official positions, such as the theory that crop rotation will maintain the fertility of the soil, but also by the ruinous policy of most commercial fertilizer interests in urging and often persuading farmers to use small amounts of high-priced so-called "complete" fertilizers which add to the soil only a fraction of the plant food actually required by the crops removed, with the inevitable result that the land itself is steadily impoverished.

The more rational system makes use of abundant quantities of all essentials, but at a cost low enough to be within reasonable reach. Those materials which are naturally contained in the soil in inexhaustible amounts are liberated from the soil and thus made available for crop production; those contained in the air are likewise drawn upon as needed; while those materials which must be purchased are bought and

applied in liberal quantities, but in low-priced forms, and then made available on the farm by economic natural methods.

Four Fundamental Facts

Nearly 150 years ago Sénébier, of Switzerland, found that the carbon of plants is derived from the carbon dioxid of the air, and it is more than a century since DeSaussure, of France, first gave to the world a correct and almost complete statement concerning the essential mineral food of plants. Later, Lawes and Gilbert, of England, established the fact that for most plants the soil must furnish the nitrogen as well as the mineral elements; and more than a quarter-century has passed since Hellriegel, of Germany, discovered that bacteria living in symbiotic relationship with legume plants have power to gather nitrogen from the inexhaustible atmospheric supply.

These are the four great fundamental facts upon which the science of plant growth and permanent fertility must be based, and they were all discovered before the Illinois Experiment Station was established.

Illinois Contributions

There remained, however, two very important general problems, and in the solution of these Illinois has made some contributions. One of these relates to the amount of nitrogen taken from the air by legumes under normal field conditions; and the other concerns the liberation of mineral plant food from insoluble materials.

It is not enough to know that clover has power to secure nitrogen from the air; we should know how much nitrogen is thus secured in order that we may plan intelligently to provide nitrogen for the production of corn, oats, wheat and other non-legumes, instead of using clover merely as a soil stimulant in systems of ultimate land ruin, as is still the most common practise.

It is also a matter of the greatest economic importance that definite information should be secured in regard to the practical means of utilizing mineral plant food from the abundant natural supplies nearest at hand, such as Tennessee phosphate rock, natural limestone, and the potassium minerals already present in our normal soils.

Plant-food Elements

In brief, there are ten elementary substances which bear the same relation to the making of crops as brick and mortar bear to a wall of masonry. If any one of these ten elements is entirely lacking, it is impossible to produce a grain of corn or wheat, a spear of grass, or a leaf of clover.

Two elements, carbon and oxygen, are taken into the plant from the air through the leaves; hydrogen is secured from water absorbed by the roots, and iron and sulphur are also supplied by nature in abundance.

But the other five elements require careful consideration if lands are to be kept fertile. These are potassium, magnesium, calcium, phosphorus and nitrogen; and every landowner ought to be as well acquainted with these five elements as he is with his five nearest neighbors.

Instead of making this acquaintance and gaining a knowledge of important facts and principles, the average farmer in the older states, with failing fertility, has made the acquaintance of the fertilizer agent; and instead of purchasing what he needs for the permanent improvement of his soil, he buys what the agent wants to sell, with the common result that the seller is enriched while the soil is merely stimulated to greater poverty.

Potassium.—A careful study of the facts shows that potassium is one of the abundant elements in nature; that the average crust of the earth contains 2½ per cent. of this element, and that normal soils bear some relation in composition to the average of the earth's crust.

If normal soil had the same percentage, then the plowed soil of an acre 6⅔ inches deep (corresponding to 2 million pounds of soil) would contain 50,000 pounds of potassium. In Illinois, the normal soils actually do contain from 25,000 to 45,000 pounds per acre of this plant-food element in the first 6⅔ inches, while less than 4 pounds of potassium would be added in an application of 200 pounds of the most common commercial fertilizer. The Illinois system of permanent fertility does not provide for the purchase of potassium for normal soils, but it does provide for the liberation of an abundance of that element from the practically inexhaustible supply in the soil. This liberation is accomplished by the action of decaying organic matter plowed under in the form of farm manure or crop residues, including clover or other legumes.

Only where the soil is positively deficient in potassium susceptible of liberation, as is the case with some sand soils and with most peaty swamp lands, need potassium be purchased in permanent systems of either grain farming or live-stock farming; but in market gardening or in raising timothy hay for the market commercial potassium may be required; and, on some worn soils especially deficient in decaying matter, temporary use of kainit is often advisable.

Magnesium and Calcium.—As a general average, normal soils contain more than four times as much potassium as magnesium, while the loss by leaching and cropping in rational systems of grain or live-stock farming may be actually greater for magnesium than for potassium, so that magnesium is more likely to become deficient in soils than is potassium.

The calcium supply in normal soils is also only one fourth that of potassium, while the average loss by cropping and leaching is four times as great, so that 16 to 1 expresses the relative importance of calcium and potassium in the problem of permanent fertility on normal soils.

All limestones contain calcium; and the common dolomitic limestone

in the almost measureless deposits contains both calcium and magnesium in very suitable form both for plant food and for correcting or preventing soil acidity.

In the Illinois system of permanent fertility, ground natural limestone is applied, where needed, at the rate of about two tons per acre every four years. With the same price and purity, probably the dolomite is preferable to the high calcium stone, although both kinds have been used with very good results. Further data from investigations now in progress are expected to furnish definite information as to the relative value of these materials.

Phosphorus.—Attention was called to the fact that two million pounds of the average crust of the earth contains 50,000 pounds of potassium; but compared with this we find only 2,000 pounds of phosphorus. Likewise, the plowed soil of an acre of average Illinois land contains about 35,000 pounds of potassium, but less than 1,200 pounds of phosphorus. When grain is sold from the farm, about equal amounts of phosphorus and potassium are carried away, while in independent systems of live-stock farming much more phosphorus than potassium leaves the farm.

At 3 cents a pound for phosphorus one can double the amount of that element contained in the plowed soil of our $200 land at a cost of $35 an acre, while to double the potassium in the same stratum would cost more than $1,000 an acre.

Phosphorus can be purchased, delivered at the farmer's railroad station in Illinois, for about 3 cents a pound in the form of fine-ground natural rock phosphate, for 10 to 12 cents a pound in steamed bone meal, or for 12 to 15 cents in acid phosphate. It can be used with profit in any of these forms, but the data thus far secured in comparative experiments plainly indicate that, with equal amounts of money invested, the natural rock phosphate will give the greatest profit in rational permanent systems. At least 1,000 pounds per acre every four years should be applied, and for the first application even three or four tons per acre is not considered too much phosphate by those who best understand the need and value of phosphorus on normal land.

Nitrogen and Organic Matter.—There is a rather common opinion that the growing of clover enriches the soil in nitrogen, and many even believe that clover in crop rotation will maintain the fertility of the soil. These same people are likely to think that the application of limestone and phosphate involves much expense and work, and that the returns are much less certain than those from other labor and money investments.

Such opinions are largely erroneous. The mere growing of clover on normal land does not enrich it. Even the nitrogen is not increased unless the clover crop is returned to the soil either directly or in farm manure. Rotation with such crops as corn, oats and clover depletes the

soil of all important elements of fertility, and on normal soils always results ultimately in land ruin, unless some system of restoration is practised. Clover takes large amounts of calcium and phosphorus from the soil, and does not increase the nitrogen content if only the roots and stubble are left, because they contain no more nitrogen than the clover itself will take from soils of normal productive power.

To increase or maintain the nitrogen and organic matter of the soil is the greatest practical problem in American agriculture. In an hour's time one can spread enough limestone or phosphate on an acre of land to provide for large crops of wheat, corn, oats and clover for ten or twenty years, while to supply the nitrogen for the same length of time would require from 20 to 40 tons of clover, or from 80 to 160 tons of farm manure, to be added to the same acre of land, even though one of the four crops harvested secured its nitrogen from the air.

Certainly we are making no such additions to the soil in average corn-belt agriculture, and one may well ask, How then is it possible to grow the crops now produced in this country? In the simplest language the answer to this question is: By "skinning" the soil—by working the land for all that's in it—by following the example of our ancestors, who brought agricultural ruin to millions of acres of once fertile farm land in the original thirteen states.

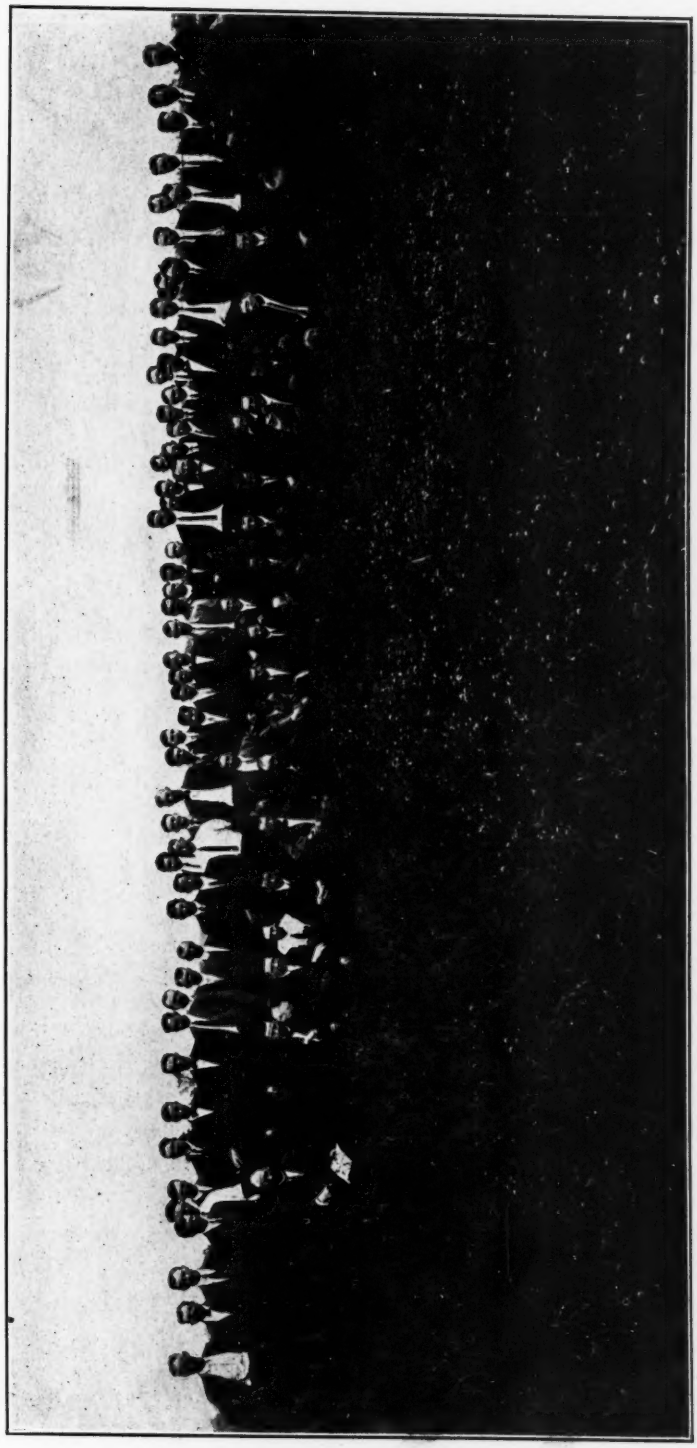
To provide nitrogen in the Illinois system of permanent agriculture requires the use of common sense and positive knowledge, the same as in providing limestone and phosphorus.

For the live-stock farmer I would suggest a five-field system—a four-year rotation of corn, corn, oats and clover, grown upon four fields for five years, while the fifth field is kept in alfalfa. At the end of the fifth year the alfalfa field is brought into the rotation and one of the four fields seeded to alfalfa for another five-year period, and so on.

If the crop yields are 50 bushels each of corn and oats, 2 tons of clover and 3 tons of alfalfa; if the straw and half the corn stalks are used for bedding and all other produce for feed, and if 60 per cent. of the nitrogen in the manure is used for the production of crops, then a system is provided which will permanently maintain the supply of nitrogen.

For the farmer who sells grain, a 25-bushel wheat crop may well be substituted for the first corn crop, clover being seeded on the wheat for plowing under next year before planting corn. If the fall and spring growths of this clover aggregate 1½ tons, and if only the grain and clover seed and the alfalfa hay are sold, all clover, stalks and straw being turned to the land, this also provides a system for the permanent maintenance of nitrogen.

If the crop yields are all increased by 50 per cent., or even by 100 per cent., these systems still provide for the nitrogen supply, unless with the larger yields on richer land a somewhat greater amount is likely to



CLASS INSPECTING POORLAND FARM. Clover, 1912. Check strip on the left. Treated land on the right.

be lost by leaching than is added in the rain and by the azotobacter and other non-symbiotic bacteria.

While these systems are distinctly for live-stock farming or for grain and hay farming, they should be considered as only suggesting the basis for solving the nitrogen problem. In diversified farming a combination of these systems will often be preferred to either one alone. The important point is that the landowner should know the essential facts and base his practise upon them in order to provide for permanent fertility with respect to nitrogen, phosphorus and limestone.

Application of Principles Established

Louisiana Experiments.—The longest record of a rational permanent system of agriculture conducted in America is furnished by the Louisiana Experiment Station. As an average of nineteen years, the values per acre of three crops were $29.79 from unfertilized land, and $92.04 where organic manures and phosphorus were regularly applied[1] in a three-year rotation of (1) cotton, (2) corn and cowpeas, (3) oats and cowpeas. Here the crop values from the well-fertilized land average more than three times as great as those from the unfertilized land under the same rotation and with two legume cover crops grown every three years.

Ohio Experiments.—The Ohio Experiment Station has reported sixteen years' results from a three-year rotation of corn, wheat and clover, both from unfertilized land and from land treated with farm manure and phosphorus. As a general average, the values per acre of the three crops at conservative prices were $27.07 on untreated[2] land, $44.65 where farm manure was applied, $53.82 where manure and rock phosphate were used, and $53.61 where manure and acid phosphate were applied, practically the same yields having been secured whether the phosphorus was applied in raw rock phosphate or in acid phosphate, costing twice as much. The well-fertilized land has produced nearly twice as much as the land where no manure and phosphate were used, although clover was grown every third year in the rotation and all of the land was limed.

On the basis of these figures, 8 tons of manure were worth $17.58, or $2.20 per ton; and the rock phosphate, costing about $7.50 or $8 per ton, was worth $57.31; or, if we use the Ohio methods of computing the amount and value of the increase produced, each ton of raw phosphate was worth $65.63; and it may well be added that to obtain the same amount of phosphorus in the common high-priced mixed manufactured commercial fertilizer, such as farmers are advised by the

[1] In addition, five pounds per acre of potassium were applied every three years.

[2] Except for lime and clover.

POORLAND FARM: Clover and timothy, 1913. Check strip.

fertilizer manufacturers and advertising agencies to use, would cost about $75.

Illinois Experiments.—As an average of 318 tests conducted in southern Illinois during a period of eight years, two tons of ground limestone, applied once in four years at a cost of about $2.50 per acre, has produced an increase of 5 bushels of corn, 6½ bushels of oats, 4 bushels of wheat and ½ ton of hay; and where one ton per acre of fine-ground rock phosphate was applied on the common corn-belt land in a rotation of wheat, corn, oats and clover, the value of the increase produce paid back more than 100 per cent. for the first crop rotation and nearly 200 per cent. for the second four-year period.

On one of our oldest soil experiment fields on typical Illinois prairie

POORLAND FARM: Clover and timothy, 1913. Regular treatment.

land, where soil enrichment has been practised for twelve years, during the last four years the value of the produce from the land receiving phosphorus has been twice as much as that from the untreated land. In other words, $2.50 invested in phosphorus has brought the same gross income as $250 invested in land; and even the interest on the land investment is five times the annual cost of the phosphorus. Furthermore, the addition of phosphorus tends toward enrichment and consequently toward the protection of the capital invested in the land.

It is sometimes suggested by people who have no intelligent basis for such an opinion, that the result secured by an experiment station upon relatively small tracts of land could not be secured in practical agriculture. In part to disprove such incorrect and unjust statements,

POORLAND FARM: Wheat, 1913. Check strip, 11½ bushels per acre.

I purchased a farm in southern Illinois ten years ago at a cost of less than $20 an acre. It comprised about 300 acres of poor gray prairie land (the commonest type of soil in about twenty counties in that part of the state) and a few acres of timber land. It was christened "Poorland Farm" by others who knew of its impoverished condition.

In 1913 a 40-acre field of this farm produced 1,320 bushels of wheat. This particular forty acres was bought at $15 an acre. It had been agriculturally abandoned for five years prior to 1904, and was covered with a scant growth of red sorrel, poverty grass and weeds.

During the ten years this field has been cropped with a rotation including one year each of corn, oats (or cowpeas) and wheat, and three

POORLAND FARM: Wheat, 1913. Regular treatment, 35½ bushels per acre.

years of meadow and pasture with clover and timothy. About 4 tons per acre of ground limestone and 2 tons per acre of fine-ground raw rock phosphate have been applied to 37 acres of this field. Two applications have been made of each material; the phosphate was plowed down for the corn crops of 1904 and 1910, and the limestone was applied in the fall and winter of 1904–5 and after the ground was plowed for wheat in the fall of 1912.

The entire 40-acre field was covered with one uniform application of six loads per acre of farm manure with a 50-bushel spreader.

A six-rod strip entirely across the field (80 rods) received the same

application of manure and the same rotation of crops as the remaining 37 acres, but no phosphate was applied to this strip, and no limestone was applied to it until the fall of 1912, when the regular application (about 2 tons per acre) was applied to one half (three rods) of the six-rod strip.

Only 39 acres of this field were seeded to wheat in the fall of 1912, a lane having been fenced off on one side; and the 1,320 bushels were produced on the 39 acres.

The actual yields were as follows:

1½ acres with farm manure alone produced 11½ bushels per acre.

1½ acres with farm manure and the one application of ground limestone produced 15 bushels per acre.

36 acres with farm manure and two applications of ground limestone and two of fine-ground phosphate produced 35½ bushels per acre.

The cost of two tons of limestone delivered at my railroad station is $2.25, and raw rock phosphate has averaged about $6.75 per ton, making $9 per acre the cost for each six years.

To this must be added the expense of hauling these materials two miles from the station and spreading them on the land, which I estimate at 50 cents per ton. This makes the average annual cost $1.75 per acre for the limestone and phosphate spread on the field, and this average annual investment resulted in the increase of 24 bushels of wheat per acre in 1913.

Thus we may say that the previous applications of these two natural stones in this system of farming brought about the production in 1913 of 864 bushels of wheat, sufficient to furnish a year's supply of bread for more than a hundred people. And the soil is not being stimulated or depleted of any element in which it is naturally deficient. On the contrary, there is positive soil enrichment; "new" nitrogen is secured from the air, the phosphorus content has already been increased to that of the $200 corn-belt land, and sour land is changed to a "limestone soil." No high-priced or artificial commercial fertilizers are used on this farm; and the results secured from 40-acre fields on a 300-acre farm are practically the same as on the one fifth-acre plots of the state experiment fields under similar systems.

Poorland Farm is usually inspected each year by my class of university students in soil fertility, about one hundred of whom saw the fields of wheat and clover in June, 1913. It is for the benefit of such as these, who desire to know the truth regarding economic systems of permanent soil improvement, that this brief statement is published.

CHABANEAU: AN EARLY WORKER ON PLATINUM

By Professor JAS. LEWIS HOWE
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NOT long since M. Louis Quennessen of Paris (head of the old house of Des Moutis & Co., platinum refiners) directed my attention to an early worker on platinum, Pierre-François Chabaneau, whose name has so far escaped the historians of chemistry that I think it is not even mentioned in any English or German work, and has only appeared in the last edition of Moissan's "Traité de Chimie Minèrale." More recently, through the courtesy of M. Quennessen, I have received a copy of an all but unknown memoir, "Notice sur Chabaneau, Chimiste Périgourdin," par M. Jules Delanoue, printed at Périgueux in 1862, portions of which appear to be of sufficient interest to put on record. This biographical sketch was written in 1857, though not published till five years later, and has for its purpose "to call to the attention of our citizens the useful work, too little known, of a modest man, who unquestionably deserves the first place among the distinguished men whom Périgord has given to the world."

It may be noted that Périgueux is the capital of the old province of Périgord (now in part Dordogne) in southwest France, and has an interesting history going back to the time when it was the old Gallic town of Vesunna, the capital of the Petrocorii. Numerous remains of Vesunna are still in existence, especially baths, temples, an aqueduct and fragments of the amphitheater, mostly dating from its Roman occupation. The most notable building of Périgueux is the cathedral of St. Front, belonging to the Byzantine period, which bears quite a close resemblance to St. Mark's at Venice. The town has undergone many vicissitudes, having been taken by the barbarians in the fourth century, the Saracens in the eighth, the Normans in the ninth, the English in the fourteenth, and later restored to the French. It was a stronghold of the Calvinists in the Huguenot wars, and at this time was nearly laid in ruins. In the midst of an agricultural region, it is perhaps best known for its truffles and chestnut-fed hogs, the latter being used in hunting for the former.

The early history of Chabaneau is a not unfamiliar one of precocity and hardship.

Pierre-François Chabaneau was born at Nontron (in northwestern Dordogne) April 21, 1754. His family were respectable artisans, and he would undoubtedly have followed the obscure career of his parents, had not his intelligence and pronounced love of study attracted the attention of his uncle, a

monk of the order of St. Antony, at Aveyron (in south-central France, a hundred or so miles from Nontron). Young Chabaneau spent several years with this uncle, pursuing his studies along ecclesiastical lines, destined for the church. He was then sent to Paris for further theological study with the Oratorians, for his uncle was evidently by no means an ascetic. Here, for the sake of his kinsman, he entered upon his studies with great ardor and made such rapid progress that he astonished his teachers; his theses were the admiration of all. Nevertheless, in spite of his brilliant successes, other influences were working on him, as is so often the case with such natures. He was not born for metaphysical studies; his inquiring disposition could not accommodate itself to the abstractions of scholastic philosophy. The unsupported scaffolding of theological hypotheses, the interminable verbiage, the halting arguments of the doctors, all failed to satisfy the spirt of the young Chabaneau and to accord with his ideas. He demanded mathematical arguments, the definiteness of figures, exact science, and not the science of paradoxes; his reason rebelled at the false ideas they sought to teach him. In his dissertations he refuted his teachers by arguments which they could not controvert, and did it so thoroughly that the furious professors finally expelled their audacious scholar, as a punishment for his independence and for his success.

Behold now our young man in the streets of Paris, in the midst of the immense Babylon, without relatives, without friends, having neither experience of the world nor yet money! The six livres, which represented his whole fortune, had been expended in the purchase of a perruque, imperiously demanded by the customs of the times. He dared not return to his angry uncle, nor indeed had he the means for the journey. A kind Providence directed him to the abbé La Rose, to whom he related his story and revealed the extreme embarrassment in which he found himself. The worthy abbé was greatly interested and offered to place him as professor of mathematics in the Jesuit college at Passy (just out of Paris), of which he was the director. The young theologian, whose studies had been confined to Greek, Latin and philosophy, was absolutely unacquainted even with arithmetic. He was greatly disappointed when he learned what his employment would be, but necessity compelled him to seize even this plank of safety; it was this or nothing. He unhesitatingly accepted the position, without venturing to acknowledge his complete ignorance of the subject he was to teach; he thought that perhaps by work and perseverance he might be able to fulfil his duties. He gave proof on this occasion of energy rare in one of his age, for he was only seventeen.

It is related of Jacques Amyot, the celebrated translator of Plutarch, that while he was a college servant, he was possessed of such a desire for knowledge, that he studied at night by the light of the fire. Young Chabaneau, whom chance and want compelled to teach others what he did not know himself, and who had great ambition to worthily carry out his task, passed the nights in preparation of the lessons for the following day. He hid his lamp, and then, when all the college world slept, lit it and worked till day. And so it was that, with indefatigable labor, aided by a powerful physical constitution, he made himself master of arithmetic, algebra and geometry. Nor did he stop with these studies; the passion for knowledge dominated him. He studied experimental physics, natural history and chemistry, that prodigious science which had just begun to give promise of the astounding wonders which have been realized in our day.

Just at this time was beginning the most active period in the work of Lavoisier, and it was the year before that he had presented to the Académie des Sciences his refutation of the supposed transformation

of water into earth, in which the balance was used as an instrument of chemical research, and which soon led to the conception of the permanence of matter and later to the overthrow of the phlogiston theory. This work of Lavoisier could not fail to make a great impression upon such a mind as that of Chabaneau.

His pupils made rapid progress; they wondered at the knowledge of the young professor, and the director, abbé La Rose, did not cease from expressing his satisfaction. . . .

Chabaneau was now about twenty years old, an age when is often born the love of independence. He knew that the knowledge which he now possessed would suffice to supply all his material needs. He therefore resigned from his position in the college of Passy, after having expressed his most sincere thanks to his benefactor, and, taking lodgings in the Rue des Mathurins, within the city, opened after the fashion of that day a course of public lectures which met with great success.

Among the most assiduous of his auditors were the young sons of the Comte de Pena-Florida, whose father had sent them to France to complete their education, and also to procure several professors for a great college for the nobility which he purposed founding at Bergara.

Bergara was a small city in the Basque province of Guipúzcoa in northern Spain, and near the bay of Biscay. It afterwards came into some prominence as the place where the treaty was signed in 1839 between Spain and the Carlists of the Basque provinces. Of the subsequent history of the college I have been able to learn nothing.

The young nobles gained the affection of their professor and made him the most brilliant offers if he would accept the direction of the college founded by their father. For a long time Chabaneau resisted, but, finally yielding to the earnest solicitation of the young marquesses and other friends, he decided to exchange France for Spain. He immediately began the study of the Spanish language, and with such ardor that in a few months he felt that he had fully mastered it.

He remained three years at Bergara, devoted himself without relaxation to scientific study, and acquired such a reputation that the king, Charles III., wishing to locate him in Madrid, created for him a public Chair of Mineralogy, Physics and Chemistry, lodged him in one of his palaces, and granted him an annual stipend of 2,200 piasters ($2,400), a very considerable sum for that time.

The inauguration of his course took place in the presence of the king and all the court. This opening lecture had for its subject the utility and the future of science, and was so remarkable that a Spanish poet composed for the occasion an ode, dedicated to the learned professor. Impelled by the love of science and wishing to justify the high favor in which he was held by the king, Chabaneau continued with great earnestness his scientific work. As he desired to enter into relations with all the learned men of Europe and to profit by their work, he recognized the necessity of studying English, Italian, German, etc. So energetic was he in his language study that at the age of twenty-five he was master of no less than eight languages, living or dead.

Charles III. provided Chabaneau with a valuable library and a laboratory, considered at that day "magnificent." All the spare moments remaining from his public instruction were devoted to the study of physics and especially of chemistry. At this period Spanish America was sending to the mint at Madrid

not only ingots of gold and silver, but also from time to time a mineral in the form of little white metallic grains, infusible and very heavy. The miners found it associated with gold and with diamonds (!) and called it *platina*, from its similarity to silver (*plata* in Spanish).

The government had no use for the platina and, fearing it might be used to debase the coinage, ordered (ineffectually) that it should be buried when extracted from the ore. Meanwhile in 1741, an Englishman named Wood gave the knowledge of platina to Europe; in 1750 Watson announced that it contained a metal hitherto unknown; in 1752 Scheffer, director of the Stockholm mint, and in 1754 Lewis in London, dispelled all doubt regarding the fact that a new metal actually existed. Baron von Sickingen proposed a method for its extraction from the ore.

The new metal, platinum, thus obtained was in the form of a powder or sponge, which resisted fusion, even in the most powerful furnace, and was thus wholly useless in the arts. Chabaneau undertook the difficult task of obtaining platinum in metallic ingots, in spite of its infusibility. He recognized that this very infusibility would give great value to objects made of this new metal.

Several other chemists of the time had busied themselves with this same problem. The only hope of success appeared to be in alloying platinum with other metals, but this seemed to present insurmountable difficulties, owing in part to the impurity of the platinum ore, and also to the large amount of other metals necessary for its solution. It was early observed (von Sickingen says by Scheffer, who wrote in 1751) that a small amount of metallic arsenic caused platinum to fuse easily, but the ingot thus obtained was exceedingly brittle. Achard (1779) found that by heating this alloy for a long time at a high temperature the arsenic was gradually volatilized, leaving a mass of platinum in a malleable condition. While his communication to the Berlin Academy is entitled "Leichte Methode, Gefässe aus Platina zu bereiten," it was nearly ten years before practical application seems to have been made of the method, and though a letter appears in *Krells Annalen* in 1790 stating that platinum vessels can be bought cheaply of Jeanty in Paris, they were actually very rare and possibly never practically used until after the close of the century. Achard's method seems, however, to have been used industrially by Jeanty as late as 1820, though the method of Chabaneau, rediscovered by Knight and possibly independently by Cock also, came into general use in the first decade of the nineteenth century. The vessels made by Achard's method could never have been satisfactory, especially owing to the difficulty of completely removing the arsenic from the platinum.

Among the nobility who had interested themselves in the founding of the college at Bergara was the Marquess of Aranda. This man (minister of state and general, in 1787 ambassador to Paris) was distinguished among all the nobles for his devotion to science. He held Chabaneau in high esteem and encouraged him strongly in his projected work upon platinum. He had the government turn over its whole supply of platinum ore to Chabaneau, and furnished him everything in his power for the laborious undertaking, Laborious indeed,

for even to-day Dumas says "of all analyses, that of platinum ore is, without contradiction, the most difficult."

In spite of the regal luxury of his laboratory, Chabaneau found at that time in Madrid fewer resources than would to-day be offered by the most unpretentious laboratory in France. Chabaneau was obliged to prepare his own reagents and make his apparatus. Chemistry was still an empiric science and Lavoisier had only just begun to bring order out of chaos. Further, at this time no one could have suspected that in addition to gold, mercury, lead, copper, iron, etc., the platinum ore contained five more metals, osmium, iridium, palladium, rhodium and ruthenium, not discovered till 1803 and 1844. Chabaneau found himself contending with six metals where he supposed there was only one, platinum. Inevitable mistakes and innumerable disappointments naturally resulted. He had proved that platinum was malleable, yet occasionally he found it despairingly brittle (this was an alloy with iridium); he knew that it was infusible, incombustible and unoxidizable, yet he was stupefied to see it at times burn and volatilize (this was the alloy with osmium).

The Marquess of Aranda, appreciating the great interest attaching to the industrial use of a metal of which Spain possessed all the mines, came often to Chabaneau's laboratory, and often found him discouraged and busying himself on other investigations. At such times Aranda, a most genial and lovable character, would console him, encourage him, and in the end bring him back to that which Aranda considered his great task, the investigation of "white gold," as it was then called. Chabaneau would take up with new zeal his tantalizing work, and so passed days and nights, months and years. At last he succeeded in surmounting all difficulties, his wearisome task was rewarded by the discovery of a process by which the metal could be purified. The effectiveness of the method was verified by several repetitions. The enchanted Marquess had him carry it out on a large scale and came to the laboratory each day with increasing interest. Judge of his astonishment and horror when one day he found Chabaneau in a frenzy engaged in throwing out the door and windows his dishes, flasks and ores, as well as all the solutions of platinum which he had prepared with so much trouble and difficulty.

The Castillian imperturbability of the Marquess only redoubled the French fury of the young chemist. "Away with it all. I'll smash the whole business," he cried in a mixture of French and the patois of Périgord. "You shall never again get me to touch the damned metal." And in fact he broke up all the apparatus of the laboratory.

Really this infantile fury was to some extent justifiable. No one knew then, and indeed few know now, that lime does not precipitate platinum in artificial light, but that in daylight the metal is completely precipitated by this reagent. Chabaneau, working with lime at night, had been enabled to precipitate all the other metals which were present in his solution, while his platinum was left unprecipitated and purified. Repeating the operation by day, platinum and all were thrown down, and he was completely at sea, without being able to suspect the reason.

Three months later, at the home of the Marquess of Aranda there appeared upon a table an ingot some ten centimeters cube, with a beautiful metallic luster; it was malleable platinum. The enthusiastic Marquess started to pick it up, but failed to move it. "You are joking," said he to Chabaneau, "you have fastened it down." "No indeed," said the professor, and he raised the little ingot easily, though it weighed some twenty-three kilograms. The Marquess had not thought that the light platinum sponge would thus appear as the heaviest of all (then known) metals.

Chabaneau's discovery consisted in compressing the platinum sponge while hot at the moment of its formation, and then hammering it several times while at a white heat. Since platinum is infusible at the highest temperature of a furnace, it is easily recognized how difficult it had been to convert the pulverulent metal into an ingot. This infusibility is, however, only relative, since Deville has since succeeded in fusing the metal with the oxygen-hydrogen blowpipe; but this property, added to a resistance to the action of acids equal to that of gold, evidently entitles platinum to rank with the precious (noble) metals.

It is to be noted that there were two necessary conditions for the preparation of malleable platinum, either of which was useless without the other. First, the metal must be obtained from the ore in a pure condition, for unless separated not only from the base metals, but also from the largest part of the other platinum metals, the sponge can not be welded into a malleable mass; second, while at a high temperature the sponge of pure platinum is easily compressed into a malleable ingot, at low temperatures it has no coherence. Virtually this process, generally attributed to Knight, was in use almost exclusively until the last third of the nineteenth century.

The king, who spent some of his leisure moments dabbling in science, often came to Chabaneau's laboratory and assisted in his experiments. He was very proud to have such a discovery made in his capital, and caused a commemorative medal to be struck in platinum. He also gave Chabaneau a life pension of 2,800 piasters ($3,000), in addition to his annual stipend of 12,000 livres, but the pension was granted only on the express condition of residence in Spain, and was to be forfeited should Chabaneau leave the kingdom. The letters-patent bear the date of 1783, and thus establish the priority of Chabaneau's discovery officially and in an incontestible manner.

Chabaneau was for some time engaged in preparing large quantities of malleable platinum. Then his patron, Marquess d'Aranda, having been appointed ambassador to France (1787), he was prevailed on to accompany him to Paris, in order to convert under his auspices some of the new metal into ornaments for the crown. Jeanetty, goldsmith to the court of France and a very able man, had been commissioned for this work, and he sought vainly to discover the process used by Chabaneau. He did, however, discover another method (alloying with arsenic) and employed it with such success that he founded in Paris a manufactory for platinum ware, which prospered down to 1820. At present the method of compression while hot, without alloying, is used, and that of Jeanetty has been abandoned.

It was only two years after this memoir was written that Deville and Debray perfected the method first proposed by Hare in 1838 of fusing platinum in the flame of the oxygen-hydrogen blowpipe. The memoir is somewhat misleading regarding the process of Jeanty (or Jeanetty), for while it is true that he did for many years manufacture platinum crucibles and other vessels by his method, it was early in the century entirely supplanted by the compression method, and it is doubtful if much practical application was ever made of it.

It is then to Chabaneau that belongs all the honor of having first discovered and employed on a large scale the only method which is in use to-day for pre-

paring a metal, so valuable for chemistry and the arts, and yet no contemporary writer has recorded the claim of our modest compatriot to the glory of this discovery. I apply to him the term modest, for in spite of all our entreaties he could never be persuaded to put forward his just claims. But to-day, as we have before our eyes the letters-patent of the Spanish government, bearing the date of 1783 and testifying to the discovery made by Chabaneau, we come to lay claim for him to the honor of incontestible priority, and to preserve his memory, ungratefully forgotten by his contemporaries.

About 1790 Chabaneau published a large work on the natural sciences in the Spanish language, which was to have been followed by several others, but which was complete as far as regards his specialty. This work, which demanded so much research, night work, and fatigue of every kind, gravely affected his health, and the court physicians prescribed a return to his native air and a period of complete repose. This rest and our climate affected him so favorably that in a few months his health was wholly regained, and he determined to renounce his pension of 15,000 francs in order to dwell in his fatherland and to end in this quiet retreat, in the bosom of his family, a life, hitherto passed among strangers in the midst of the most assiduous labors.

Retiring to the country, near Nontron, he sought to live obscurely, but the jury of the central schools of France besought him to accept the chair of physics and experimental chemistry in the École Centrale of Périgueux. The subjects were so seldom taught at this period that Chabaneau felt it the duty of a good citizen to accept the modest position. His course of lectures, which lasted two years, was printed at the expense of the administration, and published in the year VII by Canler at Périgueux.

On the suppression of the central schools he was offered a chair of chemistry at Paris, and his permission was sought to translate and publish his great work; but, well determined this time to live in his quiet retreat, he refused all these propositions, desiring only to live in solitude and to enjoy the repose so needed and so welcome after all his labors.

He died in January, 1842, at the age of 88, and left no descendant bearing his name. He lived tranquilly, isolated from the world, on his country-place of Clara, near Nontron, dividing his time, like a sage of antiquity, between rural pursuits and philosophical study.

We knew him only in his declining years, but he was then a fine-looking old man, with pleasing and regular features, bearing much resemblance to those of our good and lamented Béranger. His conversation was charming and always instructive. Friend and contemporary of Volney, of Cabanis, of Lavoisier, he was nourished upon their ideas and imbued with their spirit, and they were pleasingly reflected in his conversation.

Thus ends the story which has happily rescued for us from oblivion the life and work of one of the gifted early workers in chemistry. That his name had been forgotten is doubtless chiefly due to his own modesty, but in part also to the fact that his labors were largely carried on in Spain, and his only important published work was in that language. Whatever may be the reason, the atmosphere of Spain has never been conducive to the development of science.

THE BIOLOGIST'S PROBLEM

By Professor T. D. A. COCKERELL
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THE problem is, to be free without being absurd. Confronted by a series of types, or a series of phenomena, one attempts to classify in an original and accurate manner. In the natural sciences, it is never possible to have the whole of the facts before us. Thus, in paleontology, there is never a complete series of fossiliferous strata; in taxonomy, the materials are always more or less insufficient and must be so. Moreover, were our series of specimens complete, we should still have to reason and speculate about their history and relationships. Still again, if we could assemble and correctly arrange all the data on a given subject, the borderlands of this subject would still remain nebulous, and this no matter how far our researches might extend, unless they compassed all reality, which is impossible.

Artificially, we devise a system which, bounding and restricting facts, gives us the appearance of great precision. We solemnly discuss whether this or that fact falls within this or that artificial category, as if the category were the more real and substantial of the two. We come to know our pigeon holes better than we know the pigeons which inhabit them; and as for those birds which nest in the trees or rocks, we will have nothing to do with them. Thus there arises a species of orthodoxy, quite analogous to that of the churches. A recent writer, referring to the desire of biologists to refer the vital phenomena of certain organisms to mechanical causes, frankly expresses the opinion that "this is a laudable desire." It is laudable to try to make your facts roost in the pigeon holes already provided, rather than elsewhere. In the classification of animals and plants, workers are sometimes divided into two camps, known as the lumpers and the splitters. The lumpers say, let us use large pigeon holes for our data; for all practical purposes, fine divisions are equally useless and unnecessary. The splitters say rather, let us discriminate as finely as we can; but even they have to draw the line somewhere. It is a singular thing that the lumpers actually pride themselves on their lumping; regard it as a virtue to ignore the little facts. The splitters are never quite so self-satisfied, because they are breaking new ground, and are not so sure of themselves. Nearly every naturalist has had a queer feeling when confronted by a long series of apparently new species; a sense of the uncanny, almost a

distrust of his own eyesight. Yet in years after, when all these animals have been worked into the system, and each has a little history of its own in the literature, he is apt to find that he was really too timid when he thought himself too bold. He finds, of course, that he made mistakes, but often these are not the ones he feared he might be making.

What advice should be given to one beginning research in some field of biology? If you follow the well beaten path you will not perhaps make many discoveries, but you will not get into trouble. You will at least be biologically respectable. It seems to be the common opinion of university teachers that this is the best plan, if we may judge from the published theses of their students. These studies in cytology and ecology can be worked out much as one works out a problem in mathematics, the data being given, and the result unavoidable unless some gross blunder is made. Taxonomy is often decried by these very men as mechanical, and they avoid it in planning for doctors' theses. The fact is, that it is not mechanical enough; it is too full of ifs and ands, of uncertainties and pitfalls, and as a rule they can not deal successfully with it. On this account we are probably saved from a great deal of bad taxonomy, which would cause infinite trouble to later workers; while the actual output, if not especially brilliant, is at least useful.

From the standpoint of science it seems evident that too much originality should not be encouraged in the young. We need experience in order to deal with difficult matters and break new ground. The older a man gets the more right he has to be free, to depend upon his own judgments even when they run counter to all others. Unfortunately, however, the very experience which seems to justify freedom is the cause of its restriction. Habits are formed, prejudices are developed, the mind is worn into ruts. There are few who can be really original in later life. Thus in the matter of ability, based on knowledge and experience, there is a curve which ascends until the powers begin to fail; but in the matter of originality and freedom the curve soon drops downward, gradually perhaps, but steadily. Obviously, there must be an optimum point somewhere at which it is most possible to make scientific discoveries. It will differ according to the character of the individual and his particular environment; it is for the psychologists to determine for us where it is most likely to occur. Its determination, even approximately, ought to be of some consequence to us.[1] If it is at thirty, then at thirty our brilliant young men and women ought to be most free to do as they will; most free from external difficulties and encumbrances of every sort. Arrangements have not been made to meet

[1] If a hundred persons of good ability would submit annually to a carefully considered series of tests from the years 20 to 40, or as many of these as possible, some pertinent data might be secured. This might be possible in a large city like New York.

this need, but might they not be worth while? The history of science, literature and art alike is full of pathetic instances of men who have been to all intents and purposes enslaved at the golden time of their lives, reaching independence and opportunities for freedom only when it was too late to make much use of them.

If we had the will to make the most of what may be called the *peak of efficiency,* we might at the same time do something to increase its elevation. Nature has doubtless determined its position roughly as corresponding to the time when the growing family needs support and protection. Nature, however, has made no provision for intellectual work which benefits the race at large and in the fullness of time, rather than the individual responsible for it. The very coincidence of circumstances originally favored by natural selection here becomes a stumbling block, and we may only get around it by deliberately planning to do so. That is to say, society must adequately support scientific workers of ability at a sufficiently early age to get the best out of them. No provision for comfortable retirement at sixty-five will be of any particular value in this connection.

Granting the will to make the most of the able originality of our generation, to actively encourage the freedom of those who most deserve it from the standpoint of social utility; can we successfully pick out the right individuals? It is the experience of teachers that originality is a rare product. An eminent teacher of biology told me that he wished to put up in his laboratory the text "many are called, but few are chosen." We are most of us hunting for some genius to grow up under our care and make us famous by reflected light, even as Darwin did Henslow. Why is it that we are, on the whole, so unsuccessful in this quest? Is it that we, old fogies that we are, do not know the thing when we see it? Or is the thing so scarce that we might as well be hunting elephants in Trafalgar Square? Or again, is it that our educational system snuffs out all germs of genius in individuals originally possessing them? Perhaps all these things count in the matter; at the least, the problem is a complex one.

In literature, perhaps more than in science, we often see freedom combined with absurdity. The doctrine that genius and insanity are allied has a certain partial justification in the light of recent work on heredity. It is rare, with our extraordinary tangle of heritable qualities, for any man to have an approximately complete series of characters of the highest grade. Such men, when they occur, become famous, but what we call genius usually depends on one or a few special excellencies. A high quality is like a fine plant, which requires good supporting environment, better than that of common sorts. This should be found, not simply in outside circumstances, but more especially in the other qualities of the man himself. When it is not found there is apt to be a

breakdown somewhere. We who are commonplace and undistinguished are not offered a competency for the rest of our lives as the price of a single crooked deal; or if our tastes are cheap and vulgar, they are not enshrined in sculpture or music to go down the ages to our disgrace and the corruption of others. We keep most of our cheapness, our stupidity, our dishonesty, for ourselves and our immediate circle, and much of it is never revealed at all. In the lottery which human inheritance at present is, good qualities will commonly, when they appear, lack the support we could wish for them; but when this is true, there can be no doubt that much of the evil resulting from this can often be remedied by good social conditions. That is to say, we can help the individual to leave unstimulated the bad and to make the most of what is good. Thus, in a sense, he may actually choose his ancestors. Instead of doing this, however, I fear we often do the reverse, and especially is this true when men have to appeal to the multitude rather than to their peers. The eccentricities of modern art and literature, so foreign to the mood of the great masters of the past, may have their root in the want of adequate balance in the make-up of the workers, but they are unquestionably stimulated by a public which, as a newspaper editor once put it, must have the "gewhiz sensation" every morning. Science workers must be sheltered from such demands, and this alone is enough reason for not hastening their public fame until such time as they are too old to learn new tricks.

The much-debated question whether training in one subject increases ability in other quite diverse ones may have some bearing on the peak of efficiency. If it is possible to increase the general ability to deal with problems, without unduly prejudicing the mind in respect to the particular problems to be solved, it seems that the altitude of the peak of efficiency will be increased. The indications are that when one has reached his peak in respect to his particular line of work he may yet find another peak ahead of him by shifting his base to a limited extent. How much, as a rule, it is profitable to shift it might be determined more or less by careful enquiry. I think, however, that from this point of view there is a good deal to be said for taking up a new subject every five or ten years. Even if the altitude of the successive peaks is not increased, it is worth something to have these successive maxima of ability in a life time.

A COMPARISON OF WHITE AND COLORED CHILDREN MEASURED BY THE BINET SCALE OF INTELLIGENCE

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WHEREVER the methods of science have been inapplicable, or for some reason been left unapplied, opinion has held sway, and, as the adage has it, the number of opinions has equalled that of the men holding them. This, it need hardly be pointed out, is seen clearly in the histories and literatures of religion, philosophy, ethics, politics and many branches of the newer social sciences. It is notoriously true of discussions of race problems, even when the opinions have been held by scientists eminent in their own special domains. Thus we have a Boaz, who can see no essential difference between the negro and white races, and a Le Bon, who is equally certain that a "mental abyss" forever separates the two peoples, and that the negro is the much inferior of the two.

In the hope that the Binet tests would yield a few grains of fact which might leaven the lump of opinion, the writer directed Miss Alice C. Strong, a graduate student of the University of South Carolina, to measure with the Binet scale, as revised by Dr. H. H. Goddard, the white and colored school children of Columbia, S. C. The same tests were given to both the white and colored children under practically uniform conditions, with the exception that some of the colored children tested were older than twelve years. The course of study in the colored school, which is a part of the public school system, is essentially the same as in the white schools, and the quality of teaching is good. The children seemed to be at ease in the presence of the white examiner, and to do their best. No marked variation from the white children in the manner of responding could be noted. In almost every case the dress, cleanliness and manners of the children indicated that they came from good homes. The replies were usually couched in fewer words than those of the white children. There was less tendency to enter into conversation, and it was soon found that they were more at ease when reacting to the tests than when an attempt was made to talk with them about other things.

The following are the tests which were given to the children of both races, ranging from six to twelve years inclusive.

Six Years: (1) Is this morning or is it afternoon. (2) What is a fork? a table? a chair? a horse? a mama? (3) Do you see this key? Put it on that

chair. Then shut the door. After that bring me the box that is on the chair. Remember, first the key on the chair, then close the door, then bring the box. Do you understand? Well, then go ahead. (4) Show me your right hand. Show me your left ear. (5) Which is the prettier? (Six drawings of heads of women, three pretty and three ugly or even deformed ones, arranged so that the pretty one is now at the left and now at the right are shown the child.)

Seven Years: (1) Child must count thirteen pennies placed in a row, touching each piece with the finger as it counts. (2) Pictures representing a man and a boy drawing a cart loaded with furniture; a woman and an old man sitting on a bench in a park in winter; a man in prison looking out of the window, a couch, chair and tables are shown the child, and it is required to describe them. (3) Three unfinished drawings of a woman's head, and one of a woman with the arms missing are shown and the child is asked, What is lacking in that picture? (4) Copy with pen a diamond about three or four centimeters. (5) What is this color? (touching with the finger pieces of red, blue, green and yellow papers).

Eight Years: (1) What is the difference between a butterfly and a fly? Wood and glass? Paper and cloth? (2) Count backwards from 20 to 1. (Should be done within 20 seconds.) (3) Name the days of the week. (Must be given in order without omission within 10 seconds.) (4) Arrange in order three 1 and three 2 cent stamps. Child is asked to find by counting how much money it will take to buy them. (5) The figures 4–7–3–9–5 are repeated slowly and distinctly. The child is required to repeat them.

Nine Years: (1) Play store, using real money. Child is storekeeper, and is given some pennies, nickels and dimes with which to make change. A four-cent purchase is made, and a quarter presented. Child is required to give change. (2) Child asked to define common objects, same as in 6-year test. Definition must be better than by "use." (3) Name the day of the week, the month, the day of the month and the year. (4) Name the months of the year. (15 seconds allowed.) (5) Arranging in proper order five cubes of same size and appearance but loaded so as to weigh 6, 9, 12, 15, 18 grams.

Ten Years: (1) Naming nine pieces of money, *e. g.*, cent, nickel, dime, quarter, half dollar, dollar, two dollars, five dollars, ten dollars. (2) Draw two geometrical designs from memory. (Designs exposed 10 seconds.) (3) Repeat six figures: 854726, 274681, 941738. (4) Questions of comprehension: (*a*) What ought one to do when he is detained so that he will be late for school? (*b*) What ought one to do before taking part in an important affair? (*c*) Why does one excuse a wrong act committed in anger more easily than a wrong act committed without anger? (d) What should one do when asked his opinion of some one whom he knows only a little? (*e*) Why ought one to judge a person more by his acts than by his words? (5) Make a sentence containing the words, Columbia, money, river.

Eleven Years: (1) Find the nonsense or absurdity in the following sentences: An unfortunate cyclist had his head broken and is dead from the fall; they have taken him to the hospital and they do not think that he will recover. (*b*) I have three brothers, Paul, Ernest and myself. (*c*) The police found yesterday the body of a young girl cut into eighteen pieces. They believe that she killed herself. (*d*) Yesterday there was an accident on the railroad. But it was not serious: the number of deaths is only 48. (*e*) Some one said "If in a moment of despair I should commit suicide, I should not choose Friday, because Friday is an unlucky day and it would bring me ill luck." (2) Use three words in a sentence (same as in age ten). (3) Say as many words as you can in three minutes. (At least 60 words should be given.) (4) Give as many words as you can think of that rhyme with "day." (5) Make sentences out of these words:

Hour—for—we—early—at—park—an—started—the. To—asked—paper—my—have—teacher—correct—the—I. A—defends—dog—good—his—bravely—master.

Twelve Years: (1) Repeat the following seven figures: 2, 9, 4, 6, 3, 7, 5. 1, 6, 9, 5, 8, 4, 7. 9, 2, 8, 5, 1, 6, 4. (2) What is charity, justice, goodness? (3) Repetition of a sentence of 26 syllables. (4) A booklet of six pages contains two horizontal lines on each. On the first three pages the right line is half an inch longer than the left, on the last three the lines are of equal length. The object is to see whether the child will be able to resist the suggestion of the first three pages and see the lines on the last three as equal. (5) A person who was walking in the forest at Fontainebleau suddenly stopped much frightened and hastened to the nearest police and reported that he had seen hanging from the limb of a tree a—what? My neighbor has been having strange visitors. He has received one after the other a physician, a lawyer and a clergyman. What has happened at the house of my neighbor?

The mental age of the child is determined by the highest group of tests he can pass successfully. Only one failure is permitted in each group. If in addition to passing his group successfully the child passes as many as five tests in higher groups he is given an additional year's credit. Thus, if a seven-year-old child pass all or all but one of the seven-year tests and three of the eight and two of the nine-year tests he is rated eight years mentally. Or if he misses two tests in his group, and therefore fails, but passes five tests in higher groups he is rated as normal. If he is more than three years backward he is mentally defective. The tests begin with the group corresponding to the child's physical age, *e. g.*, a child eight years old is tested first with the eight year old tests, and then with the seven or nine, as the case may require.

The results of the investigation upon the white and colored children may be briefly summarized as follows:

	Colored, Per Cent.	White, Per Cent.
More than one year backward	29.4	10.2
Satisfactory	69.8	84.4
More than one year advanced	0.8	5.3

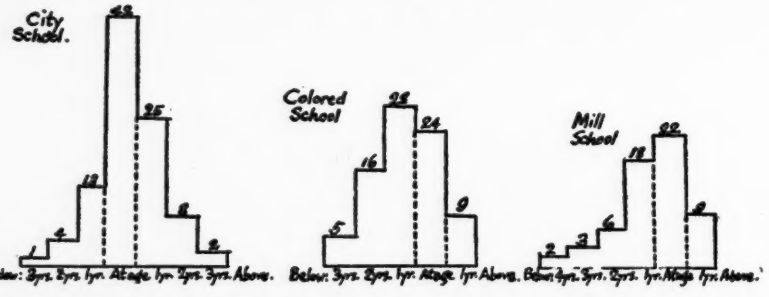
The number of white children testing at age is decidedly larger than any other group, whereas for the colored children the largest group is the one testing one year below age. In the satisfactory group there is a difference of nearly 15 per cent. between the white and colored; nearly three times as many colored are more than a year backward, and less than 1 per cent. are more than a year advanced.

The picture tests gave the colored children considerable trouble, probably due to difference in racial esthetics. The tests relating to time and money, distinguishing between morning and afternoon, enumerating the months, counting stamps and making change, the drawing tests, both copying and reproducing from memory were all too difficult. The answers to the questions of comprehension, to the absurd statements and to the problems of various facts, were often absurd or senseless; the best replies, however, compare very favorably with those

of the white children. The definitions were often not better than terms of use, and frequently stated in the language of a younger child.

In general it may be said that the colored children excel in rote memory, *e. g.*, in counting, repeating digits (but not one was able to repeat 26 syllables), naming words, making rhymes and in time orientation. They are inferior to the whites, however, in esthetic judgment, observation, reasoning, motor control, logical memory, use of words, resistance to suggestion and in orientation or adjustment to the institutions and complexities of civilized society.

To what extent these differences are due to difference in racial intellectual ability, and how much to environmental influences, differences in physiological age, or other subtle factors, can not be dogmatically stated. They are certainly not due to difference in school training. In order, therefore, to make the comparisons as just as possible, and at the same time ascertain the extent of the influence of environment, the white children were divided into two groups—city children and mill



children. The economic, educational and environmental conditions of the cotton-mill children are but little, if any, better than those of the colored children. The results of the comparison showed that the proportion of colored children who are satisfactory is less than that of the mill children, which in turn is less than that of the city children. Less than 6 per cent. of the city children are more than a year backward, 18 per cent. of the mill children, and 26 per cent. of the colored children. None of either the mill or colored children test more than one year above age, while 10 per cent. of the city children do.

These facts and the figures upon which they are based appear more vividly in the following graphs:

Another table of statistics showed that the colored children made a better showing in the first five grades than in the first seven, but their inferiority to the whites existed throughout the school years, contrary to the widespread opinion that colored children are as well, if not better, endowed during the first school years. Again, according to the Binet scale, a larger number of white children are in a school grade below their mental ability than above, whereas the reverse is true of the col-

ored children. A rough classification into three groups, according to color—dark, medium, light—showed that the darkest children are more nearly normal, the lightest show the greatest variation, both above and below normal.

The limitations of the study are evident. It is but a crude beginning of a subject that will doubtless soon be opened up and made to yield interesting and profitable data. It need not be pointed out what radical changes would have to take place in our educational theory and practise, as well as in our social philosophy, if it should be shown conclusively that races differ in mental capacity and aptitude just as they do in physical appearance. No final conclusions, however, are here offered, nor is any attempt made to settle once and for all the question of race superiority or inferiority. That requires investigation along many lines hardly opened up as yet. But this much we may surely conclude from the above study: that negro children from six to twelve and possibly fifteen years are mentally different, and also younger than southern white children of corresponding ages, and that this condition is partly due, at least, to causes that are native or racial. That is, if MM. Binet and Simon had originally tested southern negro children they would have worked out from the results a scale which would have been different from their present one in several respects, and which when applied to southern white children would be found to be, for the most part, a year or more too young, though possibly there would be some tests which would yield the opposite results.

Perhaps some day each branch of the human family will have a Binet scale of its own. Then, by a wholesale interchange of tests, as we do now with professors, it will be possible to determine wherein a given people are proficient and wherein deficient; and later, perhaps, by adding coefficients and credits to settle mooted questions of racial rank. But this again belongs to the realm of speculation.

Probably the point of greatest value brought out by this study is that perchance a key has been found in the Binet scale which will prove of the greatest service in the solution of problems in contemporary folk-psychology and race and social adjustments. Certain it is that these important human problems need the spirit, methods and instruments of science applied to them. The Binet scale is the first instrument that has appeared.

THE STRUGGLE FOR EQUALITY IN THE UNITED STATES
II

By Professor CHARLES F. EMERICK
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The Railways and Fair Play

SINCE the close of the civil war, the American people have devoted their energies largely to the development of their material resources. In 1865, the men who had served in the armies of the south as well as of the north returned to the pursuits of peace and, reinforced by the rising tide of immigration, the nation entered afresh upon the industrial conquest of its environment. Aided by the homestead act, the railway and improved farm machinery, and more recently by irrigation works and the scientific expert, the agricultural development of the country has gone forward by leaps and bounds. But material development has not been one-sided. The growth of manufactures, the increase of commerce and railway expansion, have been even more conspicuous than the development of agriculture. More noteworthy still, probably, are the changes which have taken place in the mode of businesss organization. The corporation has displaced the partnership, and the size of the business unit necessary to a maximum of efficiency has enormously increased in many fields of activity. A process of consolidation, combination and integration has gone on that has transformed the business world. The change marks nothing less than a revolution. As a consequence, the individual and small combinations of individuals find themselves in the presence of adamantine forces with which they are powerless to cope, and the conflict between equality and property has shifted to a new field. The energy and ambition of the age are so centered upon economic ends that equality of industrial opportunity is the crying need of the hour.

I

Among the new forms of property that have violated the sense of fair play, that embarked in the several fields of transportation and communication is easily chief. This is preeminently true of the railway. In a highly specialized industrial system, where nearly everything is produced for sale, the mass of commodities at some stage in its career enters the channels of transportation. Under these circumstances, equality of opportunity in the matter of reaching the market concerns the consumer as well as the producer and is fundamental to industrial

liberty. There was a time when the paramount problem in most communities was how to get a railway. After the railway came, the problem of how to make it subservient to the welfare of the community was scarcely less pressing. For it soon appeared that the railway by the adjustment of rates could decree where commodities should be produced, build up or tear down a community, and make or mar the fortunes of individuals. Besides, railway managers exercised an undue influence over the press, the actions of legislatures, executive officers and even the courts. Among the various kinds of railway favoritism, none was so invidious as the railway pass, and certainly none exerted a more subtle and corrupting influence. It gradually dawned upon the public mind that here was an industry which competition, upon which people had been accustomed to rely, was ineffective to control. Competition made for instability as well as for unjust discriminations in rates, promoted the needless construction of roads, and was therefore often ruinous alike to the investor and the shipper, and sometimes it permitted monopoly by refusing to work at all. To permit railway managers to make every rate a matter of special bargain and sale according to the supposed necessities of competition was intolerable. To leave the problem at the pleasure of the railway interests to solve by pools, rate agreements and other forms of combination, including consolidation, was to sacrifice the public interest to the greed of the few. Apparently, nothing less than the coercive power of the state was equal to the situation.

II

Probably the farmers of certain western states were the first to feel the full power of railway oppression. Long distance from market made them in a peculiar way dependent upon the railway. Since they were for the most part pioneers, they were ill prepared to stand the pecuniary losses to which they were subjected, and were quick to resent what seemed to them a manifest injustice. Besides, the fact that few of the railway bond and stockholders resided in the west made them appear as aliens, and contributed to the zeal with which the "embattled farmers" attacked the railway problem. These conditions blossomed into the granger movement which gained control of the legislatures of a number of states, and either directly by legislative enactment or indirectly through railway commissions endeavored to curb the railway power. The problem presented was almost wholly new, and the members of the different legislative bodies were without experience in meeting it. Naturally, not a little crude and ill-advised legislation resulted, but the issue between the rights of property, on the one hand, and fair play, on the other, was nevertheless fairly and squarely joined.

The railway interests did not submit to public control without a bitter contest. In defense, the attorneys of the railways banked much

upon the doctrine of charter rights announced in the Dartmouth College case, and placed great store upon the constitutional guaranties of private property to which certain decisions by state courts seemed to lend color. In 1869, the Supreme Court of Iowa decided that a railway is essentially private property and in no sense public, and in the following year the Supreme Courts of Wisconsin and Michigan handed down similar decisions.[1] In 1871, Judge Brewer, then a member of the Supreme Court of Kansas, in a dissenting opinion said:

> A railroad is founded upon an absolute property-interest. The corporation owns everything. The interests it possesses have all the attributes of absolute property.[2]

These opinions appear in cases where the right of railway companies to enforce the levying or payment of taxes voted to subsidize construction was questioned on the ground that a tax for a private purpose is invalid.

In the face of these opinions, the contention of the railway attorneys was overruled and the regulative power of the state was upheld in Munn *v.* Illinois, Ruggles *v.* Illinois and other cases. It was held that property embarked in a railway is clothed with a public purpose and therefore properly falls within the police power of the state. The fact that a railway corporation is the creature of the state, in the opinion of the Supreme Court, constituted an additional ground for state control of rates. In regard to the Dartmouth College case, the rule of strict interpretation of all charter rights was adopted. It was maintained that the right of the state to regulate railway rates can only be bargained away by language that admits of no uncertainty, that any and all doubts about the meaning of charters are to be construed in favor of the state, and that the power of the state to regulate does not lapse by non-user. In the early "granger decisions," the Supreme Court even went so far as to say that the final authority in the fixing of rates rested with the legislature and not with the courts, and that if the former reduced rates unduly the remedy of the railway interests was political rather than judicial. But in Chicago, Milwaukee and St. Paul Railway Co. *v.* Minnesota in 1890, it was held that a rate fixed by a state railway commission is subject to judicial review. Under this and subsequent decisions, the reasonableness of practically every rate fixed by a state legislature, either directly or through a commission, can be called in question in the federal courts, and the police power vested in the state legislatures is subjected to an important restriction.

[1] Iowa Supreme Court Reports, 27, p. 28. Wisconsin Supreme Court Reports, 25, p. 167. Michigan Supreme Court Reports, 20, p. 452. These references are taken from an unpublished manuscript upon "Farmers' Organizations, the Supreme Court and the Railroads," by my father, Simon Emerick.

[2] Kansas Supreme Court Reports, 7, p. 542

III

The movement to regulate railways engaged in interstate commerce has run a similar course. The Interstate Commerce Act passed by Congress in 1887 was the logical sequence of the Supreme Court in the year immediately preceding, in Wabash, St. Louis and Pacific Railway Company *v.* Illinois, deciding that the states have no right to regulate interstate commerce. Subsequent court decisions, however, so interpreted the act of 1887 as to leave the Interstate Commerce Commission without the substance of power. But successive amendments have in large measure made good its deficiencies and enlarged the scope of its authority. In 1896, the power to compel witnesses to testify was definitely obtained. The Elkins law of 1903 subjected the railway corporations which violate the law as well as their agents to a fine, and made the recipient as well as the giver of a rebate guilty of a misdemeanor. Any departure from the published rate was prohibited. In 1906, the power to fix a maximum rate was expressly granted the commission in addition to the power to declare a rate unreasonable which it already possessed. To prevent "midnight tariffs" thirty days' notice of change in rates was required. In 1910, the commission was empowered to suspend all advances in rates, and an attempt was made to clothe it with greater power in administering the long and short haul clause. The authority to establish and enforce reasonable classifications of property for transportation was also bestowed. Express and sleeping car companies, pipe lines used in transporting oil, and telegraph, telephone and cable companies have been included within the sweep of the law. Once more, plenary power over the accounts of the railways has been granted. Manifestly, if publicity and uniformity of accounts are as important to the solution of the railway problem as many suppose, the most decisive step has been taken.

Moreover, since 1906, it is no longer practicable for the carriers to disobey the orders of the commission with impunity as was previously the case. For cumulative penalties begin to run the moment an order becomes effective unless the carrier secures the intervention of a court. As a consequence, the commission has a certain standing and dignity which it has not hitherto enjoyed. It is probable also that interference by the courts will be less common in the future than in the past. The present law restricts interference to cases where the act complained of is either ultra vires or unconstitutional, and the Supreme Court decisions overruling the pretensions of the Commerce Court indicate that an established place has been won for the commission. Such are some of the more important facts incidental to a movement which has been subjecting railway property to public control in the interest of fair play.[8]

[8] Frank Haigh Dixon, "The Interstate Commerce Act as Amended in 1906," *Quarterly Journal of Economics*, Vol. 21, 1906, pp. 22–51, and the "Mann

IV

There is no doubt of the competency of the State to prescribe the weight of a loaf of bread, as it may declare what weight shall constitute a pound or a ton. But I deny the power of any Legislature under our government to fix the price which one shall receive for his property of any kind. If the power can be exercised as to one article, it may as to all articles, and the prices of everything, from a calico gown to a city mansion, may be the subject of legislative direction.[4]

So wrote Justice Field in a dissenting opinion in Munn *v.* Illinois. In the light of the general trend of court decisions as well as of legislation, it is apparent that this view is altogether too sweeping. If the highest court in the land has occasionally set at naught the railway legislation of congress and of the states, it has also brought the railways within the condemnation of the anti-trust act in the Trans-Missouri Freight, Joint Traffic and Northern Securities cases. Moreover, adverse court decisions have in large measure been overcome by additional legislation. Probably not a single member of the Supreme Bench to-day regards the view expressed by Justice Field as good law.

There has been a marked tendency during the last decade to clothe the railway commissions of the several states with more drastic powers. Some states have even gone so far as to fix rates by legislative enactment in addition to creating a commission with mandatory power.

No less than fifteen new or remodeled commissions were created in the two years 1905–1907, bringing the total number by 1908 to thirty-nine. Practically all of these were of the so-called "strong" type; that is to say, possessing the most extensive powers over all matters of rate operation and in many cases of finance as well. The most notable of these, of course, were the so-called Public Utility Commissions of Wisconsin (1905) and New York (1907). The subjugation of the formerly dominant railway interests in New Jersey and Pennsylvania was also highly significant. The movement has even invaded the New England States—so long a sanctuary of the "weak" or advisory commission. Vermont and New Hampshire set up powerful boards, . . .[5]

The consolidation of railways, the rise of freight rates in the years following 1900, "the inordinate concentration of financial power in the hands of a few privileged individuals," and the power of the newly created industrial combinations to secure concessions in rates contributed to this result.[6] The same conditions have made for more stringent federal control of the railways. Even Massachusetts has given up her advisory commission. For years this staid old commonwealth stood out for a "weak" commission. It was confidently claimed that such a commission had all the advantages of one of the strong type minus the disadvantages. On the one hand, if backed by public opinion,

Elkins Act, Amending the Act to Regulate Commerce," *ibid.*, Vol. 24, 1910, pp. 593–633.

[4] United States Supreme Court Reports, Vol. 94, 1876, p. 93.

[5] William Z. Ripley, "Railroads, Rates and Regulation," p. 629.

[6] *Ibid.*, pp. 487–492.

its recommendations had practically the same effect as a statute, for there was ever the possibility of the legislature enacting them into a law. On the other hand, if its recommendations went beyond those for which the public was willing to stand, the mistake of carrying state regulation too far was avoided. The progress of railway monopoly, however, finally carried the day for a commission with mandatory power over rates and other matters.

The chief point of attack upon the railways has been discriminations. The general average of railway rates has been so low that there has been comparatively little complaint on that score. There is, however, a pronounced tendency to subject the general average of rates to state control as railway consolidation more and more approximates a condition of monopoly. But the burden of protest has been that some rates are out of proportion to others, and the facts narrated above are but milestones in the efforts of a people to realize conditions that square more nearly with the sense of justice. Some of the legislation that has been passed has been enacted with undue haste and in a spirit of resentment, and in attempting to get rid of discriminations and at the same time preserve competition some of it has been contradictory. But to hold that it is at bottom the work of self-seeking demagogues and hair-brained agitators is to overlook the very real grievances that have existed and to underestimate the general good sense and intelligence of the people. The main trend of railway legislation in the United States is so much in accord with that in other countries as to warrant the presumption that it is moving in the right direction. As compared with those countries in which the railways are owned and operated by the state, American railway policy is moderation itself. The demand for public regulation is not a popular caprice of the moment. Its persistence and increase in the face of hostile court decisions and in spite of blundering mistakes forbid this view. In the future as in the past, "fool legislation" may result in a temporary reaction. But few railway managers look for a relaxation of governmental control, and many of them will be surprised if they do not get more. The recent Supreme Court decision in the Minnesota rate case not only upheld the authority of the state in the main, but it suggested that federal control of interstate commerce has not yet been pushed to its constitutional limits. The end is not yet in sight.

When the farmers of certain western states in the early seventies arose against the railways, there was a general disposition to treat them with contempt. Were they not a lot of ignorant frontiersmen? What chance had they against the railways? What did they know about railway management? Was not the railway in common with other industries amenable to competition? Those in the higher walks of life, with rare exceptions, deprecated the attitude of the farmers. Their position

was grossly exaggerated and misrepresented. The rantings of their more extreme spokesmen were cited as proof that they were wholly without any just ground for complaint. Many thought them bent on confiscation. The hard times following the panic of 1873 were laid at the door of the granger legislation. Nevertheless, the main contentions of the farmers were upheld by the Supreme Court. The granger movement did much toward changing the railway policy of a nation.[6a]

Professor Ripley well says:

> Great laws are not the figments of men's minds, conjured up in a day. They are a response to the needs of the time. Their true causes are thus immeasurably complex. Nor does a wholesale public demand for legislation arise overnight. From small beginnings the pressure steadily grows, oftentimes for years; until, perhaps through a conjuncture of particularly aggravating events, matters are at last brought suddenly to a head. Yet while this culmination of industrial or social pressure may finally result in legislation under some particularly strong political leadership, to assign such personal influences as even the remote cause of legislation, is to belie all the facts and experience of history. No clearer illustration of the close relationship between economic causes and statutory results could perhaps be found, than in the field of our federal legislation concerning common carriers. It forms one of the most important chapters in our industrial history.[7]

Fair Play in Other Directions

I

The demand for equality of opportunity at the hands of the railways is part of a much larger movement. The widespread protest against the undue exactions of public utility enterprises in various cities, and the creation of commissions for their control is but another phase of the same thing. Likewise, the movement for the control of the large industrial combination is at bottom a demand for fair play. The revolt against the business methods exemplified by the Standard Oil and the American Tobacco Companies made these concerns so notorious that the Supreme Court ordered their dissolution. In the course of these decisions, price-cutting limited to a portion of the market or to a single line of goods produced by a trust, trade wars which aim at buying up com-

[6a] Solus Justus Buck, "The Granger Movement," Chapters IV., V. and VI.

[7] William Z. Ripley, *op. cit.*, pp. 441–442. Hadley's "Railroad Transportation" and Johnson's "American Railway Transportation" contain good accounts of the movement for state and federal control of railways in the United States. These two works also contain accounts of the relations of the state to the railways in the principal countries of Europe. Ripley's "Railroads: Rates and Regulation" gives a sympathetic and detailed account of the movement for the control of railway rates by the federal government, but treats only incidentally of the activities of the several states. "Railway Problems," by the same author, contains an excellent selection of reprints. Merritt's "Federal Regulation of Railway Rates" contains a digest of the more important cases that have been decided by the Inter-state Commerce Commission.

peting plants and at closing them down, refusal to sell or to allow the customary discounts to purchasers who buy any of their supplies from a competing establishment—these and like methods which aim at excluding others from any industry by playing upon their fears were either expressly or by inference condemned. Trade agreements which bind large numbers of capable men for long periods not to compete in a specified field were also held anti-social. These methods were judged unfair not by any new code of ethics but in the light of the time-honored principles of the common law.

The extremity of the remedy sanctioned by the Circuit Court to which the American Tobacco Company was remanded for dissolution is noteworthy. Not only was the company disintegrated into four new companies, but each of the four was forbidden to control more than forty per cent. of its branch of the business, or within a period of five years to acquire any stock in one of the others. Twenty-nine individual defendants were enjoined for three years from increasing their holdings of stock in the new companies. For a term of five years, moreover, no two of the new companies shall have the same person serving as an officer or director, or employ the same agency for the purchase or sale of tobacco or other material.[8] It is more than doubtful whether these and similar remedies approved by the court will prove adequate to restore competition. But be this as it may, we have here limitations upon ownership in the interest of the public weal that would hardly have been thought possible a generation ago. There is the possibility therefore of still more drastic restrictions in the future if those already resorted to fall short of their purpose. It is noteworthy, also, that the Chief Justice in writing the Standard Oil and the Tobacco decisions did not question the power of Congress, under the commerce clause of the constitution, to limit the quantity of property which an individual may acquire and own, or the power to interfere with the right to acquire and own stock granted a corporation by a state, though he emphasized both of these points at length in his dissenting opinion in the Northern Securities case, Chief Justice Fuller, Justice Peekham and Justice Holmes concurring.[9] Neither did the case of the United States *v.* E. C. Knight Co. upon which the defendants banked much stand them in good stead.[10] The open-mindedness of the court augurs well for the future.

II

The spirit of fair play is expressing itself in sundry other directions. The movements against child labor and for compulsory education are cases in point. These movements aim at starting the members of the

[8] *The New York Sun*, November 9, 1911, pp. 1–2.

[9] William Z. Ripley, "Trusts, Pools and Corporations," p. 379.

[10] United States Supreme Court Reports, Vol. 52, L. ed., October, 1910, p. 648.

next generation on more equal terms in life. The tendency is to emphasize parental obligation rather than the claims parents have upon their children. As the opportunity to acquire a free hold on the public lands has diminished, the necessity of creating other opportunities by education has come to be more generally recognized. Hence the growing liberality with which the public school systems and the state universities are supported by taxation. Trade and continuation schools are helping to bring the individual into better adjustment with his environment. The splendid system of high schools in New York City is the work of the last fifteen years. The metropolis has also undertaken to provide adults with education upon all sorts of subjects by means of lectures. Not only have the obligations of parenthood increased, but man's masterful position in the home has declined. The common law has been modified until the property rights of the married woman in many states are essentially on a par with those of the married man, or at least the trend of affairs is clearly in this direction. The idea that woman is man's inferior is in growing disrepute, and one avenue of usefulness after another is being opened to her. The movement for "votes for women" is progressing rapidly throughout the civilized world. Likewise, the health of the common man has ceased to be a matter of indifference and has become a matter of public concern. The fact that no portion of society is safe so long as any portion is left to fester and rot is more fully understood and acted upon than ever before. The fall in the death rate indicates an improvement in the state of the masses of mankind. Such scourges as yellow fever and cholera have apparently been banished, and well-defined limits set to the ravages of smallpox, diphtheria, scarlet fever and many other diseases. Again, the enactment of more stringent corrupt practises acts aims at abridging the influence which the property-owning classes exert in public affairs.

III

The insistent demand for direct primaries, the initiative, the referendum and the recall indicate a disposition on the part of the rank and file to have more to say in our political and civic life. The object of these institutions is to make our representatives more truly responsible to those whom they are supposed to represent. They evidence the popular distrust in which our legislative bodies are held. They are the result and not the cause of the failures of representative government. They are the weapons with which the people are seeking to defend themselves against the aggressions of office-seekers and the property-holding class. The one-time boss of Cincinnati, George B. Cox, was recently quoted as saying:

> I made good in politics because I never lied to any one and because I never went back on a friend. What is more, despite some criticism to the contrary, I always tried to serve the people.

What is here recognized as an afterthought, it is hoped direct primaries, the initiative, the referendum and the recall will compel every politician to keep uppermost in mind. It is clear that the efficiency of these institutions depends upon the intelligence and good sense of the people. Unless used with discretion, they will prove to be as useless as a rusty knife. Conspicuous instances of their utility, however, are not lacking. But for the referendum the Cincinnati Southern Railway would have been sold away from the city for a tithe of what it was worth, just as the streets of the city were handed over for fifty years as a gift to a street railway monopoly. Lecky tells us:

> In England, a large class of politicians are now preaching a multiplication of small democratic local legislatures as the true efflorescence and perfection of democracy. In America, no fact is more clearly established than that such legislatures almost invariably fall into the hands of caucuses, wire-pullers, and professional politicians, and become centers of jobbing and corruption. One of the main tasks of the best American politicians has, of late years, been to withdraw gradually the greater part of legislation from the influence of these bodies, and to entrust it to conventions specially elected for a special purpose, and empowered to pass particular laws, subject to direct ratification by a popular vote.[11]

Among other things expressive of the spirit of the times is the reduction of tariff duties, the movement for currency reform, the reform of the general property tax, the income tax and socialism. The first aims at taking the determination of tariff schedules out of the hands of special interests, or, at least, at imposing some restraint upon them other than their own moderation. There is no more reason why the beneficiaries of the tariff should be given a free hand in fixing tariff rates than there is why one business man should permit another with whom he deals to fix the price without let or hindrance. The second aims at preventing the general distress which the collapse of our banking system now and then occasions. It also seeks to prevent the concentrated control of banking in the hands of the few and to place the facilities of credit at the disposal of every one entitled to them. The third and fourth seek to distribute the burden of state and federal taxes in a more equitable manner and to tap additional sources of revenue. The general property tax in many states involves gross inequality in the assessment of realty and the total escape of the bulk of personalty from taxation. Much is to be said in favor of the income tax in comparison with the tariff on sugar. The sugar industry does not promise to become self-supporting. As a young industry, therefore, it is hardly worthy of further protection. The whole of the income tax will go to the government, whereas part of the enhanced price of sugar has gone into the pockets of the sugar producers. Moreover, sugar is an article of general consumption and an import duty upon it is practically a capitation tax. On the other hand, an income tax is based roughly upon ability to pay. If col-

[11] "Democracy and Liberty," Vol. 1, p. 282.

lected at the source, it can not be evaded. The tax on sugar has excited little protest because it has been paid unconsciously. It has been concealed in the price. "Few people taste the tax on sugar in their tea." There is little likelihood of such a tax being shifted upon the well-to-do. It is practically certain, however, that the incidence of the income tax will fall in part upon this class. "Historically considered, income taxes have been more or less successful efforts to throw an increased share of public expenses upon the wealthy."[11a] The fifth, socialism, sums up the drift of the age towards property better than any other word. It expresses the humanitarianism of the time. Tenement house owners and steamship companies are confronted with regulations that are growing more stringent. Private property in the wasting resources of nature is being abridged in the interest of posterity. The liability of employers to employees for accidents is increasing. Assumption of risk, contributory negligence, and the fellow servant doctrine are fast being abrogated by statute. A system of social insurance is being instituted that is distributing the unmerited hardships due to accidents, sickness, old age and unemployment in a more equitable manner. There is no more indubitable sign of progress toward the ideal of equality. Factory legislation is spreading and is becoming more exacting. The hours of labor are more and more being regulated in the interest of the public health and safety. The fixing of minimum rates of wages is seriously discussed. Social legislation is looked upon as promotive rather than as subversive of liberty and a new conception of liberty is gaining ground.

Fundamentally, socialism is not a disease but a symptom and a remedy for a disordered social condition. For this reason it demands serious attention and can not be laughed out of court. No political party is immune from its influence, but the rapid increase in the vote of the Socialist party, the growing volume of discontent, and the large vote polled by the newly organized Progressive party in 1912 indicate that neither of our two historic parties has been keeping step properly with the times. Many people vainly imagine that socialism can be disposed of by pointing out the absurdity of certain of the dogmas of Marx, such as the class struggle and surplus value, to which some doctrinaires subscribe. Nothing can well be farther from the mark. The only effective way to meet socialism is to correct the economic and social conditions which account for its origin and existence.

Men do not become discontented because they have theories, but have theories, because they are discontented.[12]

[11a] Winthrop More Daniels, "The Elements of Public Finance," p. 187.

[12] Walter E. Weyl, *op. cit.*, p. 189.

(To be continued.)

THE DEMOCRATIC ORGANIZATION OF A STATE UNIVERSITY

By Professor JOSEPH K. HART
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DEMOCRACY has been working for more than a century to understand its own genesis and genius; but not enough attention has been paid to the most central element in the development of the complete democracy of the future. We have talked too much about ideals, but not enough about methods of realizing our ideals. Fallacious methods prevent the attainment of the things we most desire.

It is felt by many, perhaps by most, that self-government demands particularly strenuous processes of education in the development of the young. This is an ideal: but it has not been felt by many that a democratic social order must see to it that the public education institutions shall be thoroughly democratic in all their parts—in methods, in processes, in atmosphere, in actual results, as well as in ideals; and that this democratizing of our educational institutions is the most fundamental problem of democracy.

One type of American teacher has distinctly taken the attitude that the public schools must be absolute monarchies, with the head teacher as monarch and all other members of the school as his subjects, vassals and slaves, in order that these ideals might be compelled in all of them. A great American teacher has said that the school is the modern representative of the old Roman Empire with its arbitrary demands that the barbarians shall yield to the civilizing influences of education.

But, as stated above, it would seem that if education in a democracy is to be for democracy it must be democratic in every respect. The school, claiming to be the intellectual institution of the community, should be able to recognize the logic of such a statement and accept it.

This should certainly be true in the case of the university of a state, at least. Usually a university claims to be the center of intelligence of the state. But, if it is to be recognized as the center of intelligence in the democracy, it should be willing to take the most intelligently democratic point of view that is attainable.

Under a completely democratic conception of education what will be the nature of the organization of a state university? Such an institution attempts to bring together two rather inharmonious ideals or points of view, and usually one or the other of these ideals secures an

undue advantage, thereby limiting the work that should be accomplished by the whole institution. The primary ideal of a state university should be *service to the state*. As a great modern teacher has said, our "State universities should be training schools for servants of the common weal." But as *institutions* universities tend to take upon themselves conventional ways and to become ends in themselves; or to set up ends of their own, which are to some degree unrelated to the purposes which underlie their original foundation in the civic life. Even a state university may come to feel that it has its own sufficient standards and its own complete internal tests as to what should be considered the constituents of its own success.

The university ideal has always been an aristocratic rather than a democratic ideal, and it is with difficulty that the state university accommodates itself completely to the democratic ideal of service to the whole state. That old aristocratic ideal has held that culture is a possession of the exceptional individual and an adornment of living, rather than a great social goal and the preparation of all individuals for real service in the common good.

How can these two ideals—the one of public service, the other of personal culture—be harmonized in a state university? The real problem that faces any such an institution at any time is this: how can we keep the university ideal of a great institution of learning, and at the same time keep the state's ideal of service to the welfare of the whole people? It is easy to become purely formal, on the one hand, and to insist that learning is its own excuse for being; that the idea of use degrades culture; and that the state can well afford to support an institution devoted to the purposes of learning, whether that learning have any actual relationship to the life and problems of the state or not. On the other hand, it is almost as easy to take a purely utilitarian view of such an institution and to assert that any sort of activity that can call itself service to the people is worth doing, and that any sort of development of learning in the abstract is a waste of the state's resources.

Neither of these two tendencies must be permitted to become dominant. Each is an extreme from which the institution must be saved. Formal culture is not a democratic ideal; neither is a purely utilitarian "service to the state" taken by itself. The former becomes aristocratic and unsocial; the latter becomes inane, futile, useless. How can the state university maintain both these ideals, the one, of learning, the other, of service, at the same time? How can it make sure that these two ideals shall mutually nourish, criticize and develop each other?

In the first place there should be a board of control, made up of representatives of the people, who have a real interest in the development of such a completely democratic institution. This board should be inclusive of the whole social life of the state—industrial, professional,

commercial, cultural—and in addition they should have some comprehension of the *inner meanings of education.* That is to say, they should be men and women who realize that the world moves on, and that education is central in that movement.

They should have, for their services as representatives of the people in the control of the state's highest institutions of learning, a broadly social conception of education, and an understanding of the power of truth, a real love of truth, and a belief in the growth of truth in the life of the individual and the state.

There should be also on this board of control at least one member, man or woman, who understands something about the scientific nature of educational methods and processes, so that the board will be able to determine, by *its own intelligence,* whether the work of the university is being well done or not.

The members should be able to form for themselves a great working conception of the purposes of a state university and a general working program for such an institution. Such a conception will rightly gather around some such ideal as the following: A state university is a group of men and women of all degrees of general development, from the boys and girls just in from high school, to the mature men and women who may be leaders of the thought and action of the state. Whether young or old, these members of the university should all be students—seekers after truth, sincerely interested in life and its problems. But first of all they should be real men and women, real citizens of the state, and real members of society.

At the lower fringe of the group they may be primarily learners, at the upper fringe primarily teachers; but, both above and below, and especially in the great central main mass of the group there should be a natural and healthy mingling of the two attitudes. That is, they should be students, who are learning and teaching, and teachers who are instructing and learning.

So, all in all, a state university should be a group of men and women who are trained, and are in training, for service in the actual life and problems of the state; who are becoming intelligent in their work, and who are preparing to help the state solve its present and future problems, as true *state's men* and *state's women,* servants of the commonwealth and leaders in the constructive, democratic life of the state. And if they are not of this type, then there is no real reason why they should be members of the university, as teachers; and if they can not reach this point of view, there is no real reason why they should remain as students.

There should be, as president of the university, a man of broadly democratic and social intelligence, interested in all aspects of education and capable of understanding the meaning of democratic service for the state. The executive attitude and interests should be profoundly public,

civic, social. In no sense should the executive feel a personal ownership in the university; but he should have a sense of personal responsibility, that the university must be administered in such ways that the present democratic aspirations of the state for a larger life may be met and the future democratic life of the commonwealth may be provided.

For these reasons one of the executive's chief characteristics should be his ability to appreciate men and his willingness to judge of the worth of men for membership in the university, either as teachers or as students, by the promise that they show of ability to contribute something constructive to the progress of democracy. At the present time, in many schools, the efficiency of strong men is lessened by the petty tyrannies of executive control and by undemocratic forms of domineering authority which serve no purpose save the satisfaction of the petty tyrant involved. The president should see to it that the strong men and women of the university faculty are given broad freedom to work, both within and without the university, at those constructive programs which they are prepared to offer. The president's real service to the university and the state is not in his own exaltation; but only in his securing to the university a field for broadly social educational work, and in his securing teachers of the right sort to occupy this field. There are men in every university who have these broadest ideals of social scholarship, "learning at work in the service of the state," who need to have larger freedom for their work.

Such a president will, however, scarcely ever be chosen by a board of control acting independently. As a matter of fact a democratic organization of the university would demand that the people of the state, represented by the board of control, the faculty, represented by a committee elected by themselves, and the student body, represented by a committee chosen in the same way, should all have a share in the selection of the president. He is to be the representative of the people. He is to work with the faculty. He is to be a leader and an inspirer of the student body. How can he be all of these unless all of these interests have some share in his choice? The state might well pay any sum needed to secure such a man.

If we turn for a moment to a more definite discussion of the faculty, it should be said that a faculty for such an institution should be made up, mostly, of real teachers; that is, of men and women who are interested in teaching young men and women rather than in research work, and who have just enough of the research ideal to give them zest for their work and to keep them, intellectually, active and young.

There should be, undoubtedly, in each department a real research man, whose main function should be to stimulate the constant growth of the department along intellectual lines. But the faculty as a whole should be interested primarily in the social outcome of education rather

than in the purely intellectual outcome. They should be trained teachers with the social point of view; that is, with a conception of truth as something that comes up out of the great social world and returns into the greater social world to make life more complete and worth while.

There should be no teaching of the younger members of the university by mere research men. The first contact of the freshman with the university should be with the broadest and sanest members of the faculty. That is to say, the faculty should be strong enough to be able to afford real teachers for the freshmen. There is more to be said with reference to the organization of the faculty and the university in general, but before proceeding to that a brief statement is necessary here about the student body.

The student body is, of course, the most important part of the university. The rest of the university exists for the sake of the student body. A university student body is always, under normal conditions, an inspiring body.

In turn, they should be constantly inspired. They should be so carefully looked over on their entrance to the university that the state may be perfectly assured that none is among them merely to waste time and squander the resources of the state and his own life.

And thus assured of their interests and their ability, the students should have some real share, some genuine control in the organization and life of the university. The university exists to minister to the growing life of the students. It should be used by them as a means to their education; and since education is a broadly social process, the university must recognize its broadly social meanings and organize itself, democratically, along all the lines that minister to, that support, that compel or nourish any element of democratic personality. The spirit of genuine cooperation and effectiveness should be apparent everywhere; and old-time aristocratic suspicions of the student body should be done away with. Real training for democratic living can come only through sharing real responsibility.

Let us now return to a more complete discussion of the organization of the university. The whole faculty, every member being present or accounted for, should come together daily for at least a week before the regular opening of the school term in the fall. Out of the incidental or special studies of the summer, the experiences in travel or investigation, or the broadening influences of reaction, every member of the faculty should have something valuable to suggest with reference to the growing problems of the institution and the necessary policies. He who has nothing to suggest as to policy should be regarded as only half a member of the faculty: teaching is not all of university life. Each member of the faculty should feel a share in the determination of

policies. All suggestions should be presented in organized form, so stated to secure easy reference to appropriate committees.

These suggestions should be turned over, for analysis and recommendation, to the official committees of the faculty. There should be a large number of these and they should deal with all aspects of the scholastic and social life of the institution. The first few days of the faculty meetings may very well be given over to committee meetings of various kinds. Every member of the faculty should be a member of some official faculty committee, each thus being engaged in helping to work out the official policies of the institution. On the latter days of this week of meetings there should be regular meetings of the full faculty, every man present or accounted for, at which the constructive program of the university year shall be thoroughly considered.

All new suggestions should be carefully gone over in appropriate committees; all new problems considered in full; all the larger needs of the institution fully and freely discussed, both in committee meetings and in appropriate faculty meetings. The result of this week's work of individuals, faculties and committees should be, in the main, the determination of the general institutional policies for the year.

The regular faculty meetings should be for real discussion and deliberation; and it should be distinctly understood that the deliberations are worth something and that the decisions are to become the actual policies of the university, to be really administered by the officials of the institution, within the limits of the university's resources. A large university policy made up of suggestions offered freely by members of the faculty and worked out by the faculty itself in its own corporate meetings will command the loyalty and support of the faculty in a new way; and it will give some excuse for holding faculty meetings.

In addition to all these things, however, there should be a large number of *voluntary committees,* working with the organization and under general control of the university policy, having no authority to bind the university in any specific way, but simply helping in making the university policy successful. Every member of the faculty should be a member of some one of these voluntary committees. These opportunities for university service are unlimited; but there should be such voluntary committees on the following lines, at least:

1. Athletics: There should be in addition to the official committee on athletics a voluntary committee of fifteen or twenty members of the faculty loosely working together *to secure a larger participation* of the student body and faculty alike in athletics and physical education activities of all sorts. This committee should be composed of men and women interested in all forms of athletics and physical education, and it should work with class officers, with fraternities and sororities, and all other sorts of organizations in developing a larger university atten-

tion to intra-university physical education, and especially outdoor sports. It is likely that this should be a faculty-student cooperative committee.

2. On social affairs and social life: One of the constant complaints made in the average university is with reference to the lack of interest on the part of the faculty in the social life of the student body; and it is a more or less disgraceful fact that a very large number of the university students and faculty as well have practically no part in what is ordinarily called the social life. A committee of cordially cooperating faculty-student membership could do very much towards minimizing some of the excesses of social life on the part of some and the unhealthy lack of social life on the part of others. Perhaps the most important part of the committee's work might be the interesting of faculty members in the actualities of the social life of the school. There should be no attempt, of course, to dictate in any sense at all, but only to cooperate in securing to every individual some normal exercise of his social instincts.

3. On student activities: Every student should take part in some non-scholastic enterprise about the school. At the present time some students have too many of these enterprises in their control, while others are probably just to that extent prevented from having any real share in the out-of-school interests of the student body. Such a committee, of course, could make itself officiously offensive, but a committee of teachers who had not enough tact to be helpful in matters of this kind certainly would be made up of men and women who have no business to be teaching. Such a committee should have a large membership and should be organized to help promote all phases of legitimate "student activity" in the university.

4. On religious and moral problems in the university: Our state universities are lacking in their provision for the larger religious and moral enterprises. Officially, perhaps, little can be done by the school; but a volunteer committee, working with student organizations, can do very much to save those organizations from becoming insipid and to secure to the student body some actual participation in the world's treasures of religious culture, and to help them find their vital relationship to the real work of the world along religious and moral lines.

5. On relationships with the state at large: Here is, perhaps, one of the most important opportunities for such volunteer committee work. The committee should be made up of a strong group of men and women who are vitally interested in the problems of the state. The committee might well be a sort of critical directorate and moral support for the university extension work. It should feel perfectly free to criticize that extension work when it does not seem to be getting proper results in its plans for the state; and it should not hesitate to present

plans to the university as to its opportunities in relation to the state.

Doubtless there are other lines also in which volunteer committees of interested men and women could be of equal service to the university, to the student body, and to the state at large, but these are enough to illustrate the possibility involved.

The one point which needs to be made clear is this, that every member of the university faculty ought to have a chance to share in some real way in the determination of the policies of the university, and in shaping its integral social destiny. Otherwise, such members will either dry up into mere scholastic bean-pods in which their knowledge will rattle around, or else they will become disgusted with the bare formalities of the university and resign to go into work that offers larger opportunities for the use of real intelligence.

Complaint is often heard that faculty meetings are lifeless and dry. The reason is that the committee work of the average faculty is *monopolized by a few members who take the attitude of dictators of policies,* which the many are expected to follow; these being asked, at stated intervals, to come in from their scholastic duties to vote to confirm the determination of the makers of the policies. The arguments of committee members are usually dogmatic and dictatorial under this system, and the question of the non-committee members are usually scholastic and formal, for they have usually no interest in and little knowledge of the subject.

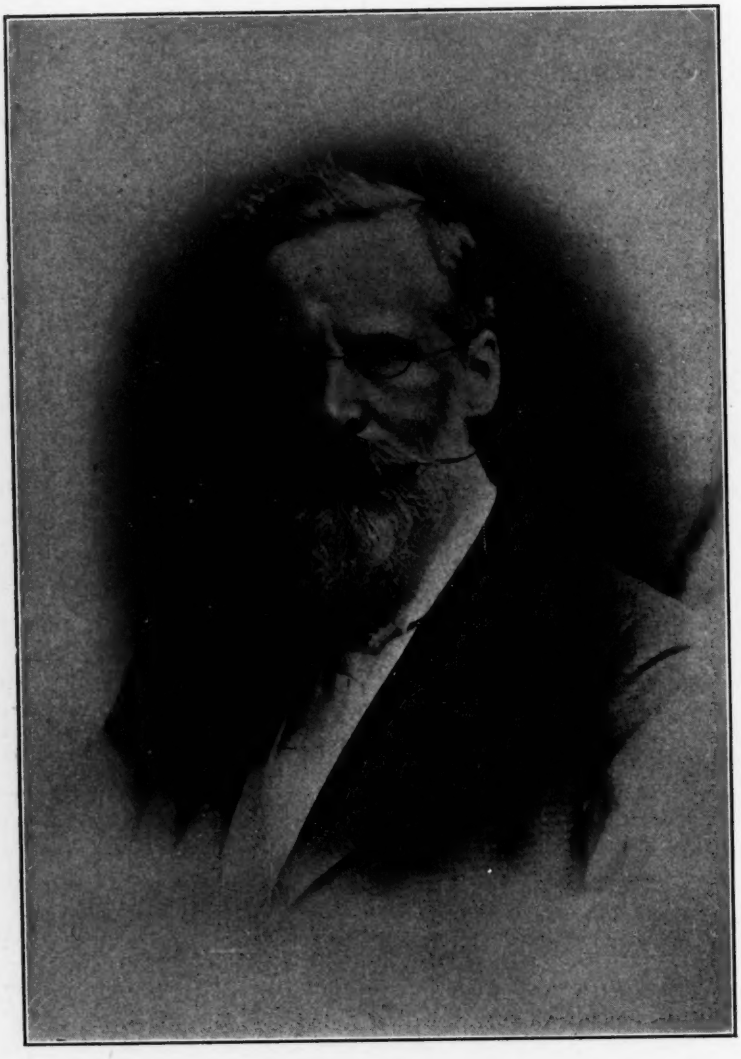
Now no man can be a real teacher in his class room, in the larger social sense demanded by our modern world, who has not had some share in determining the actual conditions and policies under which that class-room work is conducted. Every man worthy of being a teacher is worthy of having some part in determining the conditions under which he teaches. Every man worthy of having a position in a university at all has some intelligence with reference to the organization and the educational policy of such an institution. In so far as he has such intelligence the state is being defrauded if that intelligence is not called into use in helping to determine policies. Aristocratic conceptions of authority should not blind us to these facts.

Certainly there is nothing more anomalous in all our modern world than an undemocratic character in the very institutions which we boast of as being the training schools of democracy. How such undemocratic institutions fail to train for real democratic living is being shown in the fact of the all but complete failure of the school in relation to democratic living. Certainly the schools, and especially the university, ought to be able to work out processes of real democratic administration within themselves as the chief centers of democratic progress.

Such a plan, as proposed above, with all the corollaries implied but not expressed, is very possible of execution. Not only is it possible, but

if our higher education is to be really for democracy, such organization must soon come to be. When it does come it will include much more than is set forth above. Among other things, it will include larger recognition of the fact that the student body is an integral and most important part of the university; and that in all questions affecting the real policy of the university the student body must have a chance to express its deliberate will in a democratic sort of way. But before that chance comes to the student body it is likely that the problem of the democratic participation by the faculty in the actual affairs of the university must be solved.

Doubtless, monarchical, arbitrary, undemocratic ways of doing things will remain longer in the schools than anywhere else, strange as that may seem. But doubtless, even in the schools, there will some time be found enough intelligence to bring to an end such undemocratic survivals from the time of absolute monarchies, and to a beginning the organization of education along lines that will make democracy the very atmosphere of life, in school, out of school, and in all the constructive years that follow school.



SIR WILLIAM CROOKES,

elected to the presidency of the Royal Society.

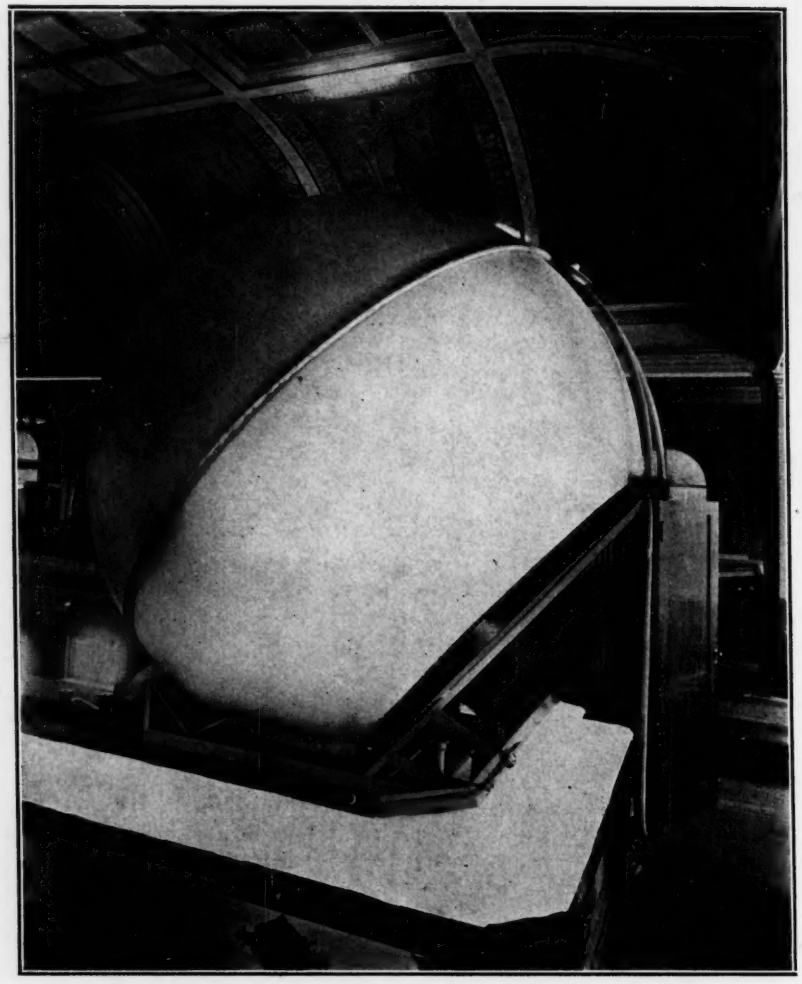
THE PROGRESS OF SCIENCE

THE ANNIVERSARY MEETING OF THE ROYAL SOCIETY

At the anniversary meeting of the Royal Society held on December 1, Sir William Crookes was elected to the presidency in succession to Sir Archibald Geikie. As a change in this office is made only once in five years, election to it is the highest honor for a British man of science, the immediate predecessors of Sir Archibald Geikie having been Sir William Huggins, Lord Lister, Lord Rayleigh and Lord Kelvin, a roll of scientific distinction which it would be difficult to parallel. Sir William Crookes was born in 1832, and thus belongs to the group of great men of the Victorian era. As long ago as 1862 he discovered thallium, and the weighing of this element in a vacuum led to the construction of the radiometer and to researches on the phenomena produced by the discharge of electricity through the exhausted tubes to which his name has been given. In his theory of radiant matter, he anticipated the electron theory. He has continued his researches with unabated vigor. In his presidential address before the British Association in 1898 he announced the discovery of monium and in connection with his work on the rare earths developed a theory of the evolution of the elements. Even since the discovery of radium he has made important researches, inventing the spinthariscope, which exhibits the results of radium emanation on a screen.

The report of the council and the address of the president review the work of the society. The government gives the society rooms at Burlington House and two grants, one of £4,000 for scientific researches and one of £1,000 for publication. The society is, however, only a trustee to award the grant for scientific research, and, as Sir Archibald Geikie pointed out, the funds of the society are not commensurate with the work it accomplishes. The Catalogue of Scientific Papers, supported mainly by gifts from the late Ludwig Mond, and the International Catalogue of Scientific Literature are expensive enterprises. The tenth annual issue of the International Catalogue has been published, with the exception of the volumes on physiology and bacteriology. A meeting of the International Council will be held in 1914, at which it will be necessary to consider seriously the question of continuing the catalogue. The society received last year the bequest made by Lord Lister of about $45,000 and a gift of $25,000 from Sir James Caird to be used in five yearly disbursements for the furtherance of physical research.

At the anniversary dinner the principal toast, that of "The Royal Society" was proposed by Mr. Page, the American ambassador. He suggested that the explanation of the bankruptcy of great literature might be the rise of science, which had changed all our outlook on the world, and had for the first time made us feel at home in this life and unafraid, had for the moment thrown men of great artistic power somewhat out of the use of their powers. It was a pleasing thought, he said, to suppose that some member of that society, or some similar body, might make a new era by the production of great literature, because the great literature of the future must take account of and must be shaped by the view of life under the dispensation of men of science. Sir Ray Lankester and Sir Harold Dixon responded for the medallists; the former having received the Copley medal and the latter one of the royal



SIDE VIEW OF THE ATWOOD CELESTIAL SPHERE FROM WEST, showing entrance.

medals. The Huygens medal was conferred on Dr. Alexander Graham Bell, of whom the president said: "His preponderating share in the invention of the telephone, now so long ago as 1876, and his practical investigations in phonetics, have laid modern civilization under deep obligation to him, while his numerous other inventions and experiments show the fertility of his genius."

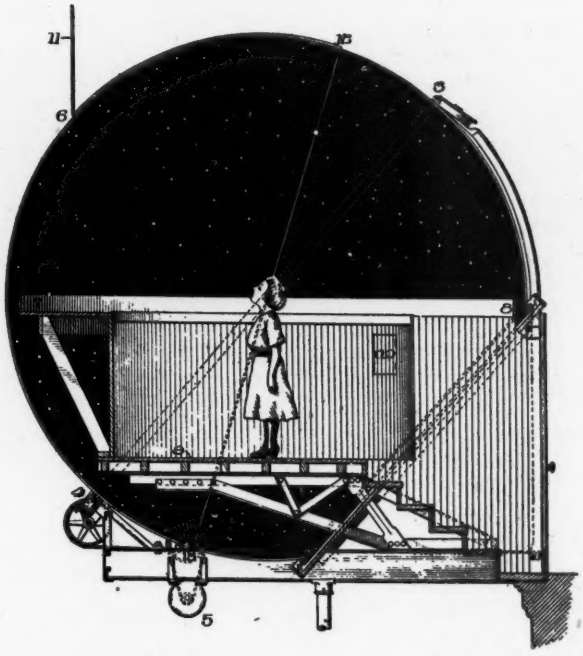
A CELESTIAL SPHERE IN A NATURAL HISTORY MUSEUM

THE Chicago Academy of Sciences has appreciated the interest in astronomy and the difficulty met in trying to become familiar with even the brighter stars and more commonly known constellations. Various plans for promoting this study were considered by the academy. The flat star charts are confusing to the untrained observer, and the globes on the outside of which stars are sometimes represented are unsatisfactory. To avoid these difficulties the sphere now in the academy building and here shown in illustrations was invented by Dr. Wallace W. Atwood, secretary of the society and director of the

museum. It was constructed, installed and presented to the academy by Mr. La Verne W. Noyes, president of the board of trustees, in order to broaden and to promote the educational and scientific work of the academy.

The material used in constructing the sphere is light galvanized sheetiron, which has been pressed to the proper curvature and soldered to the equatorial ring and to a smaller ring about the entrance to the sphere. The platform and horizon table are of wood and rest upon a steel frame. The diameter of the sphere is fifteen feet. The weight, exclusive of the platform, is a little more than 500 pounds. This weight is caried by a 2½" tube attached to the outside of the sphere along the line of the equator and resting upon three wheels as shown in the cross section view. The two lower wheels carry the greater portion of the weight, but the third and upper wheel, above the door, resists a certain thrust due to the inclined position of the sphere. The stationary platform within the sphere is supported in part by steel trusses resting upon the framework of the museum balcony, and in part by two upright pillars which rest upon the great I beam of the main floor of the museum. This platform carries a circular horizon table, below which the sphere is obscured from view, and above which there is a complete hemisphere on which the stars are represented.

The observer in this sphere is located on the surface of the earth at north latitude 41° 50′. Celestial spheres constructed for localities having other latitudes north or south would be placed at other angles and certain other constellations would be shown. The stars are represented by tiny perforations in the sphere, different sizes being used for stars of different magnitudes. The size



NORTH-SOUTH CROSS SECTION OF SPHERE. 1-2. South Polar Ring at entrance. 3. Upper Wheel supporting sphere. 4. One of two lower wheels which support the sphere and are propelled by motor. 5. Electric Motor. 6. North Pole of the heavens. 7-8. Horizon Table. 9. Observers' Platform. 10. Switch Board. 11. Electric Wire. 12-13. Ecliptic or apparent path of the sun.

and location of each star in the sphere has been determined with great care, so that the sphere is an accurate miniature representation of the heavens. The stars of the first, second, third, fourth and a selected number of those of the fifth magnitude visible from the latitude of Chicago are represented in the sphere, and the total number is 692. The shifting positions of the planets Jupiter, Saturn, Mars and Venus among the constellations have been provided for by a number of openings made to represent the different positions of each of these planets at different times of the year. The openings not in use are very readily covered. The sun is represented by a small electric light which may be moved from place to place along the ecliptic and thus be kept in its appropriate place among the stars. The moon will be represented by a series of small discs cut to represent its various phases and coated with a luminous salt. These discs may be moved from point to point along the orbit of the moon and thus represent that body in its appropriate position in the heavens.

Each star in the sphere has been numbered and star tables have been prepared so that it is simple for one to identify a particular star observed in the sphere or to locate a given star or constellation. Many of the mathematical conceptions necessary for the study of descriptive astronomy which often discourage the beginner are made with this sphere perfectly simple. Any one, including the younger school children, can with its aid become familiar with the chief constellations, their apparent movement, the brighter stars and the real and apparent movements of the sun, moon and planets.

SCIENTIFIC ITEMS

WE regret to record the death of Sir Robert Stawell Ball, Lowndean professor of astronomy at Cambridge University; of Sir John Batty Tuke, M.D., lecturer on insanity at Edinburgh; of Dr. Henry Potonié, geologist of the Prussian Geological Survey, and of Dr. Edwin Klebs, the well-known German pathologist.

DR. AUBREY STRAHAN has been appointed director of the British Geological Survey and Museum in succession to Dr. J. J. H. Teall, who will retire on January 5.—Provost Edgar F. Smith, of the University of Pennsylvania, has been elected a member of the board of trustees of the Carnegie Foundation for the Advancement of Teaching to succeed Dr. Ira Remsen, recently president of the Johns Hopkins University.

AT the meeting of the National Association of State Universities, which was held recently in Washington, D. C., a committee was appointed to draw up plans and policies to be submitted to congress for its approval. A bill will be presented asking for $500,000 as the first step in the organization.

SHORTLY after the issue of this number of the MONTHLY the scientific societies will hold their annual convocation week meetings. The American Association for the Advancement of Science meets in Atlanta, beginning on Monday, December 29. With it meet the national scientific societies devoted to astronomy, physics, entomology and botany. The societies concerned with zoology, physiology and anatomy meet in Philadelphia, the geologists in Princeton, the anthropologists in New York, the psychologists and philosophers in New Haven, the economists and sociologists in Minneapolis.